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**FINAL
TECHNICAL PLAN**

**OLEUM PLANT PHASE 2 REMEDIAL INVESTIGATION
MANUFACTURING AREA
JOLIET ARMY AMMUNITION PLANT
JOLIET, ILLINOIS**

Contract No. DAAA15-90-D-0015
Task Order No. 6

Prepared for:

**U.S. ARMY ENVIRONMENTAL CENTER
Aberdeen Proving Ground, Maryland 21010**

Prepared by:

**DAMES & MOORE, INC.
7101 Wisconsin Avenue
Suite 700
Bethesda, Maryland 20814**

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13. ABSTRACT (Maximum 200 words) This Phase 2 (PH2) Remedial Investigation (RI) Technical Plan was prepared for the Oleum Plant located at the Manufacturing Area of Joliet Army Ammunition Plant (JAAP), Joliet, Illinois. This plan was prepared in accordance with the Federal Facilities Agreement (FFA) between the U.S. Army Environmental Center (USAEC; formerly USATHAMA), U.S. Environmental Protection Agency (EPA), Region V, and Illinois EPA. The plan presents the planned PH2 field investigation at the site. The purpose of the plan is to provide the sampling procedures and rationale for the proposed sampling activities that are intended to fill data gaps identified during the implementation of the Phase 1 field activities. The data gathered during the implementation of this plan will be used to define the nature and extent of contamination and to assess potential risks to human health and the environment posed by any contamination detected.			
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ACRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
BNAs	Base-neutral/acid extractable compounds
cm/sec	Centimeters per second
EPA	U.S. Environmental Protection Agency
ft/yr	Feet per year
IAG	Interagency Agreement
ID	Inner diameter
IRQAP	Installation Restoration Quality Assurance Program
IRS	Installation Restoration Surveys
JAAP	Joliet Army Ammunition Plant
LAP	Load, assemble, package
MFG	Manufacturing Area
MW	Monitoring well
NERI	Northeast Research Institute, Inc.
NPDES	National Pollutant Discharge Elimination System
OPSC	Oleum plant soil core
PH1, PH2	Phase 1, Phase 2
ppb	Parts per billion
QAPP	Quality Assurance Project Plan
QA/QC	Quality assurance/quality control
RI	Remedial Investigation
SOP	Standard Operating Procedure
TAL	Target Analyte List
TCL	Target Compound List
TOC	Top of casing
USAEC	U.S. Army Environmental Center
VOCs	Volatile organic compounds
WSW	Water supply well

1.0 INTRODUCTION

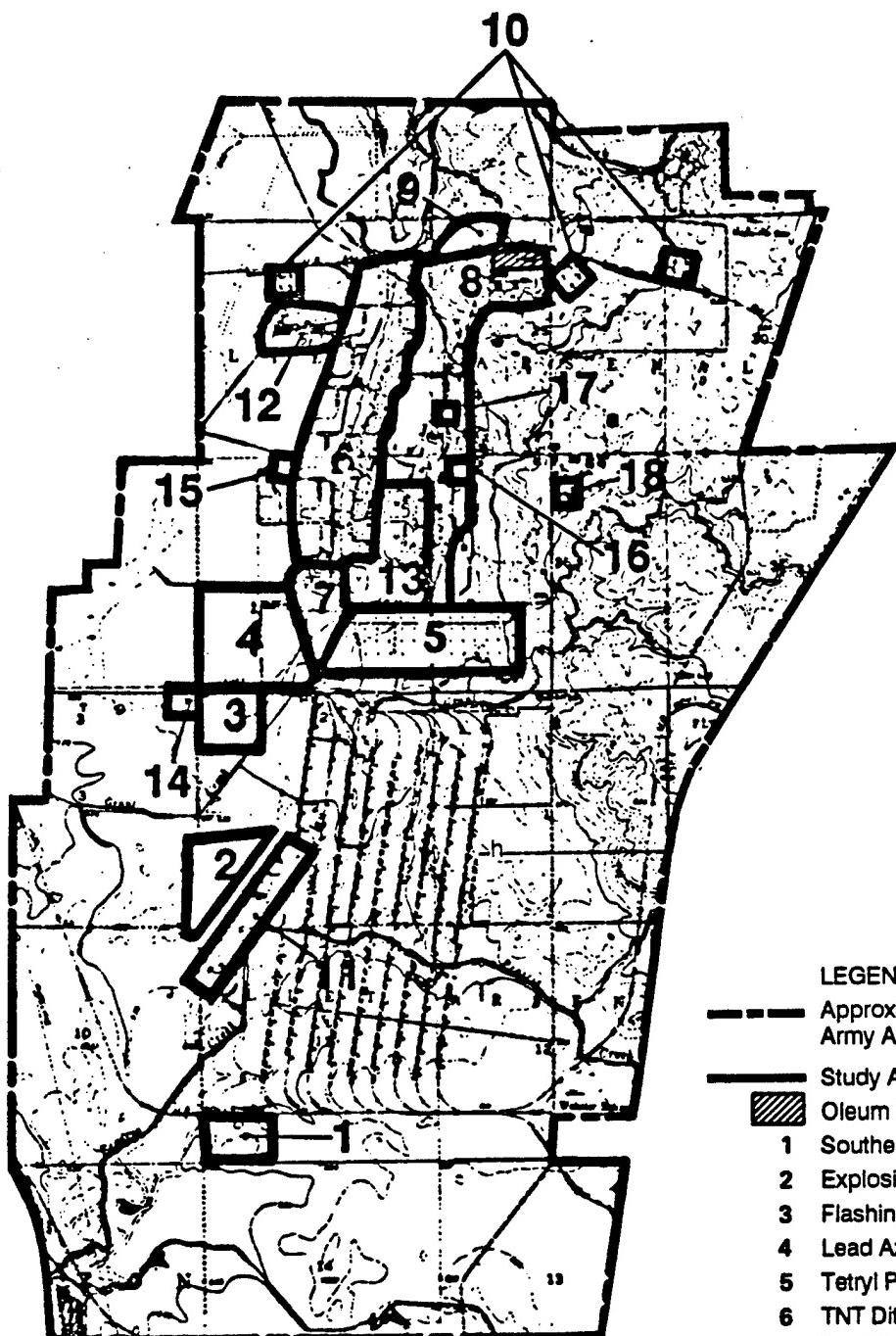
1.1 PURPOSE

This document is the Technical Plan for the Phase 2 (PH2) Remedial Investigation (RI) of the Oleum Plant in the Manufacturing (MFG) Area of Joliet Army Ammunition Plant (JAAP). It is submitted to the U.S. Army Environmental Center (USAEC)--formerly USATHAMA--under the requirements of Task Order No. 6, RI at the Manufacturing Area of JAAP, of Contract No. DAAA-15-90-D-0015. This work is being conducted in accordance with the Federal Facility Agreement (FFA) between the U.S. Army, the U.S. Environmental Protection Agency (EPA), and the Illinois EPA.

The primary purpose of the work described in this Technical Plan is to evaluate the source and extent of the volatile organic compounds (VOCs) detected in groundwater at the Oleum Plant during the initial (PH1) Oleum Plant RI. This is considered a PH2 investigation, because the data gathered during the initial RI of the Oleum Plant were not sufficient to fully characterize the extent of contamination or the source of VOCs in groundwater. Because the VOC groundwater constituents detected at the Oleum Plant were also detected downgradient of the Northern Acid Area, wells at the Acid Manufacturing Area and Northern Ash Pile will be resampled to investigate if a VOC plume exists. Additional sampling is also proposed to further define the extent of water-soluble sulfate contamination detected in groundwater and soil at the Oleum Plant. This investigation will provide information for the planned demolition and remediation of the Oleum Plant.

1.2 SITE BACKGROUND

The Oleum Plant, located within the JAAP MFG Acid Manufacturing Area (see Figure 1-1), produced oleum, a mixture of sulfuric acid and sulfur trioxide. Oleum was produced in the Northern Acid Area by Wilson Chemical Company, which operated the plant on a lease basis until January 1974. Oleum and nitric acid mixes were used at JAAP to nitrate toluene for 2,4,6-trinitrotoluene production. The Oleum



LEGEND:

- Approximate Boundary, Joliet Army Ammunition Plant
- Study Area Boundary
- Oleum Plant
- 1 Southern Ash Pile
- 2 Explosive Burning Ground
- 3 Flashing Grounds
- 4 Lead Azide Area
- 5 Tetryl Production Area
- 6 TNT Ditch Complex
- 7 Red Water Area
- 8 Acid Manufacturing Area
- 9 Northern Ash Pile
- 10 Toluene Tank Farms
- 11 Landfill
- 12 Sellite Manufacturing Area
- 13 Gravel Pits
- 14 Former Pond Area
- 15 Former Sewage Treatment Plant
- 16 Motor Pool Area
- 17 Laundry Facility
- 18 Herbicide Storage Area

FIGURE 1-1
THE OLEUM PLANT AND THE MANUFACTURING AREA
OF JOLIET ARMY AMMUNITION PLANT, ILLINOIS

Plant is illustrated on Figure 1-2. Facilities for receiving and storing raw materials for oleum production and shipping were located in the southern half of the plant, and included railroad spurs and open concrete and brick storage pads for raw sulfur. Oleum storage tanks were located in the southeast and southwest corners of the area, along the railroad spurs. Oleum production occurred in the northern half of the plant, where boilers, sulfur melting pits, sulfur furnaces, gas filters, converters, and acid drying, absorption, and cooling towers were located. Oleum was also stored in tanks in the northwestern portion of the plant.

The production of oleum required raw sulfur, 96 percent sulfuric acid, and water. Raw sulfur was melted and sprayed into sulfur furnaces, yielding sulfur trioxide gas. Combustion gas impurities were filtered, and gas temperatures were regulated by a series of converters, heat exchangers, and sulfur trioxide gas coolers. Sulfur trioxide gas flowed through a series of drying, absorption, and acid towers, where 96 percent sulfuric acid was mixed with the gas to produce oleum. Oleum was mixed with antifreeze (composed primarily of ethylene glycol) after its production. No other chemicals were used directly in the production process at this site, nor were any of the chemicals used known to contain VOCs.

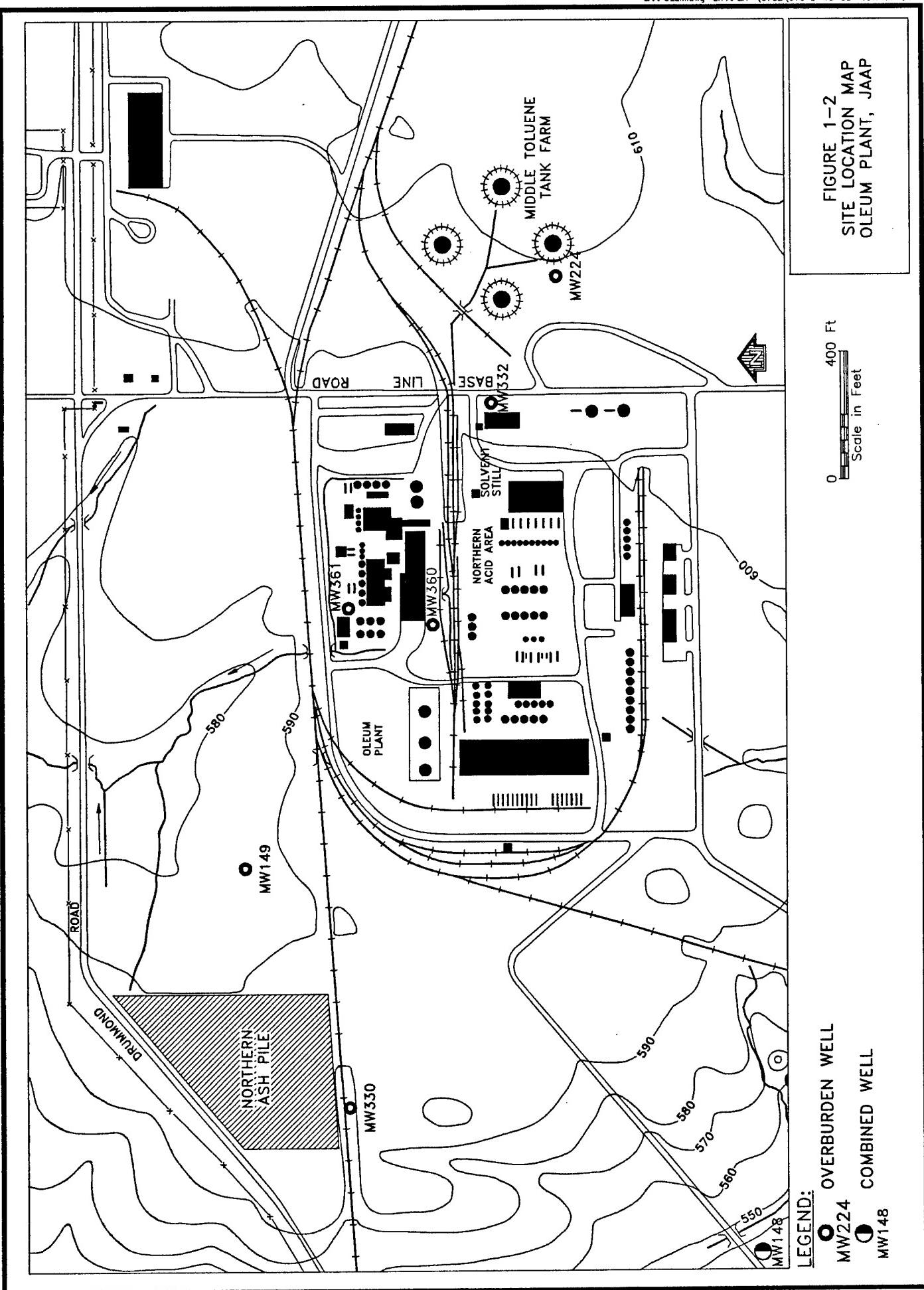
The Oleum Plant was active until January 1974, but has not been operated or maintained since its closure. Currently the plant is slated for demolition, and its buildings and machinery are heavily rusted and damaged. Raw sulfur is visible over much of the southern half of the site. Raw sulfur accumulations remain along the railroad spurs; on the ground north, west, and south of the storage pads (but not on the pads themselves); near the sulfur melting pits and furnaces; and in the drainage ditch west of the site. Only small amounts of sulfur were observed on the soil surface in the northern half of the plant.

The Northern Acid Area, located immediately south of the Oleum Plant (see Figure 1-2) produced nitric and sulfuric acids. The materials used and wastewaters generated in the area were comprised of acids, nitrous oxides, and sulfur. Ammonia was used to produce weak nitric acid by the ammonia oxidation process (AOP), and

FIGURE 1-2
SITE LOCATION MAP
OLEUM PLANT, JAAP

400 Ft
Scale in Feet

LEGEND:
 MW224 OVERBURDEN WELL
 MW148 COMBINED WELL
 MW149



the weak nitric acid was concentrated in a Nitric Acid Concentrator (NAC). Sulfuric acid production in this area used a contact process involving oxidation of sulfide. Sulfuric acid concentration (SAC) in the area involved distillation. In addition to the acid production facilities, a solvent still was located in the Northern Acid Area, and was upgradient of the Oleum Plant. The still reportedly contained tetrachloride, however, the use of the still is unknown.

1.3 ENVIRONMENTAL SETTING

1.3.1 Topography and Surface Water Hydrology

The Oleum Plant and surrounding areas are characterized by relatively flat topography with only localized areas of relief. A gentle slope to the northwest and an east-west running berm in the south effectively channel all surface runoff to the northwest. As shown in Figure 1-2, drainage is facilitated by a series of perimeter ditches that empty into a larger ditch leading northwest to a Jackson Creek tributary. The drainage ditch located west of six oleum storage tanks is a concrete-lined culvert that channels runoff from the area beneath the road toward the tributary. Because of the flatness of the terrain, surface water also tends to pool in low-lying areas and evaporate or infiltrate into the soil.

1.3.2 Hydrogeology

Subsurface conditions at the Oleum Plant were interpreted from an analysis of boring logs and water level measurements from monitoring wells MW360 and MW361, as well as two existing wells, MW149 and MW224. Table 1-1 summarizes the data from these wells. Lithologic data from the wells were used to construct the cross section illustrated in Figure 1-3. The location of this cross section is shown on Figure 1-4.

Based on the lithologic logs, soil at the Oleum Plant can be divided into two distinct units. The first unit consists of organic brown, silty topsoil, with some sand and fine gravels. It ranges in thickness from 2 to 5 feet. Underlying this layer is an unsorted, olive-gray clay unit, with traces of sand and gravel. From analysis of the

TABLE 1-1

Monitoring Well Data
Oleum Plant RI, JAAP

Well No.	Investigation(a)	Well Installation Date	Screened Interval(b)	Ground Elevation (feet)	Depth of Well (feet)	TOC Elevation (feet) (c)	Water Elevation (feet)	Date Measured	Hydraulic Conductivity (cm/sec)
MW149	IRS	04/15/81	U	584.7	36.5	587.03	561.43	11/20/92	--
MW224	PH1 RI	04/14/88	U	604.5	18.0	606.52	604.01	11/20/92	--
MW332	PH2 RI	08/05/91	U	604.4	23.0	606.64	601.21	11/18/91	--
MW360	OP RI	11/16/92	U	594.5	25.0	596.66	589.68	11/20/92	4.0E-05
MW361	OP RI	11/17/92	U	591.0	20.3	593.17	585.86	11/20/92	1.9E-05

NOTES:

- (a) IRS: Installation Restoration Surveys, Donohue & Associates, November 1982
- PH1 RI: Phase 1 Remedial Investigation, Dames & Moore, 1990a
- PH2 RI: Phase 2 Remedial Investigation, Dames & Moore, 1993
- OP RI: Oleum Plant Remedial Investigation, Dames & Moore, 1993
- (b) U = Overburden
- (c) TOC = Top of PVC casing

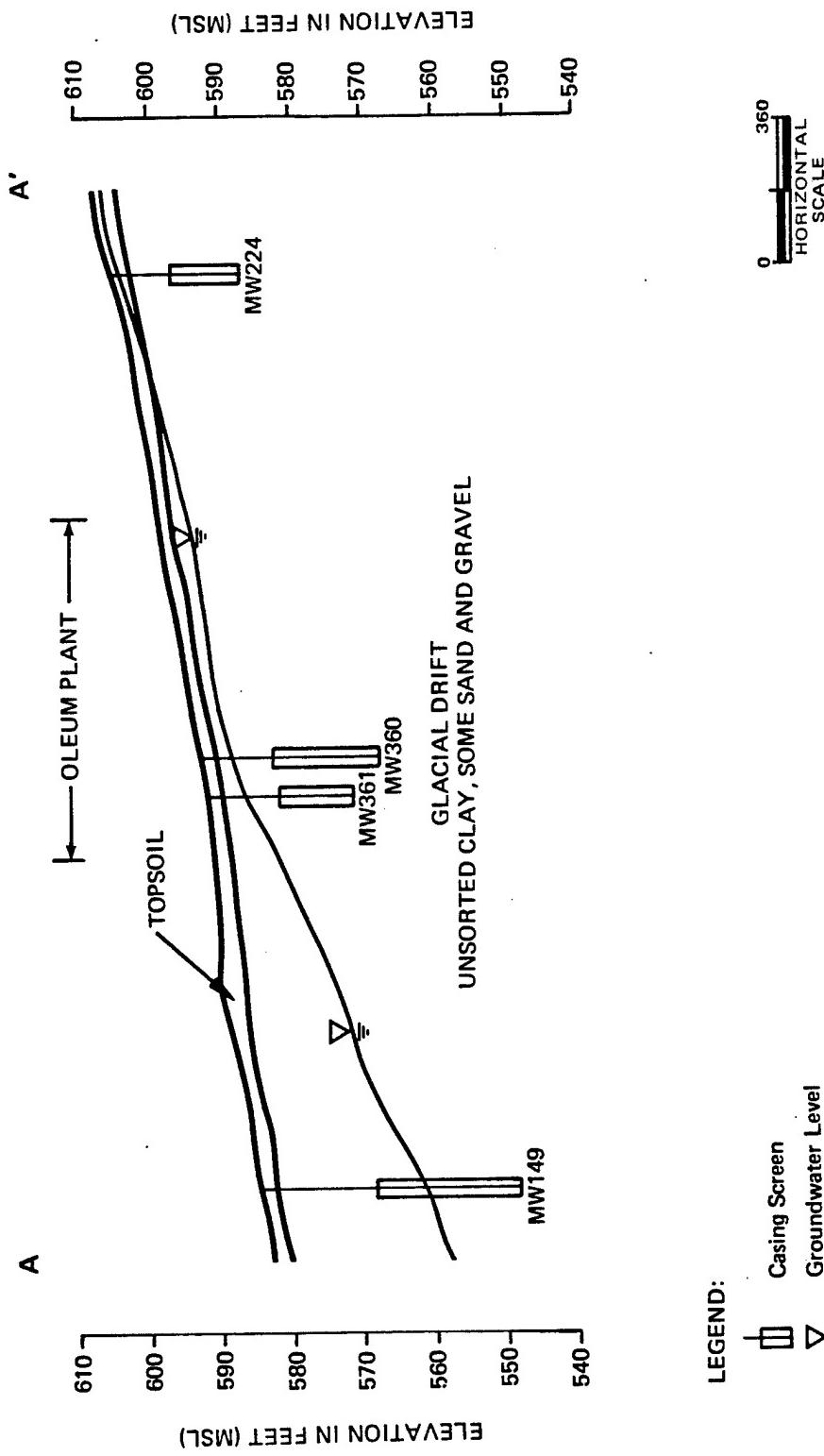
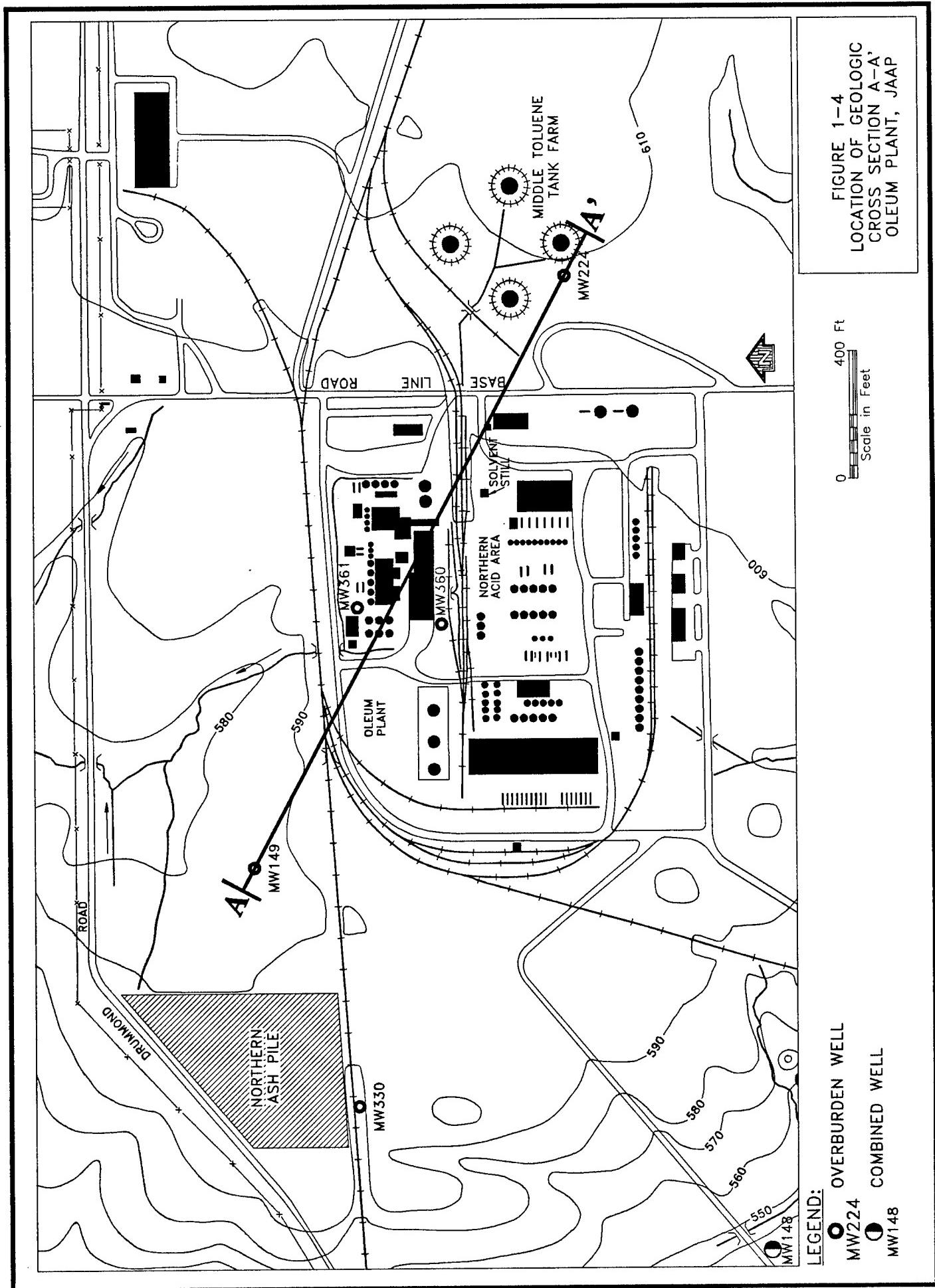
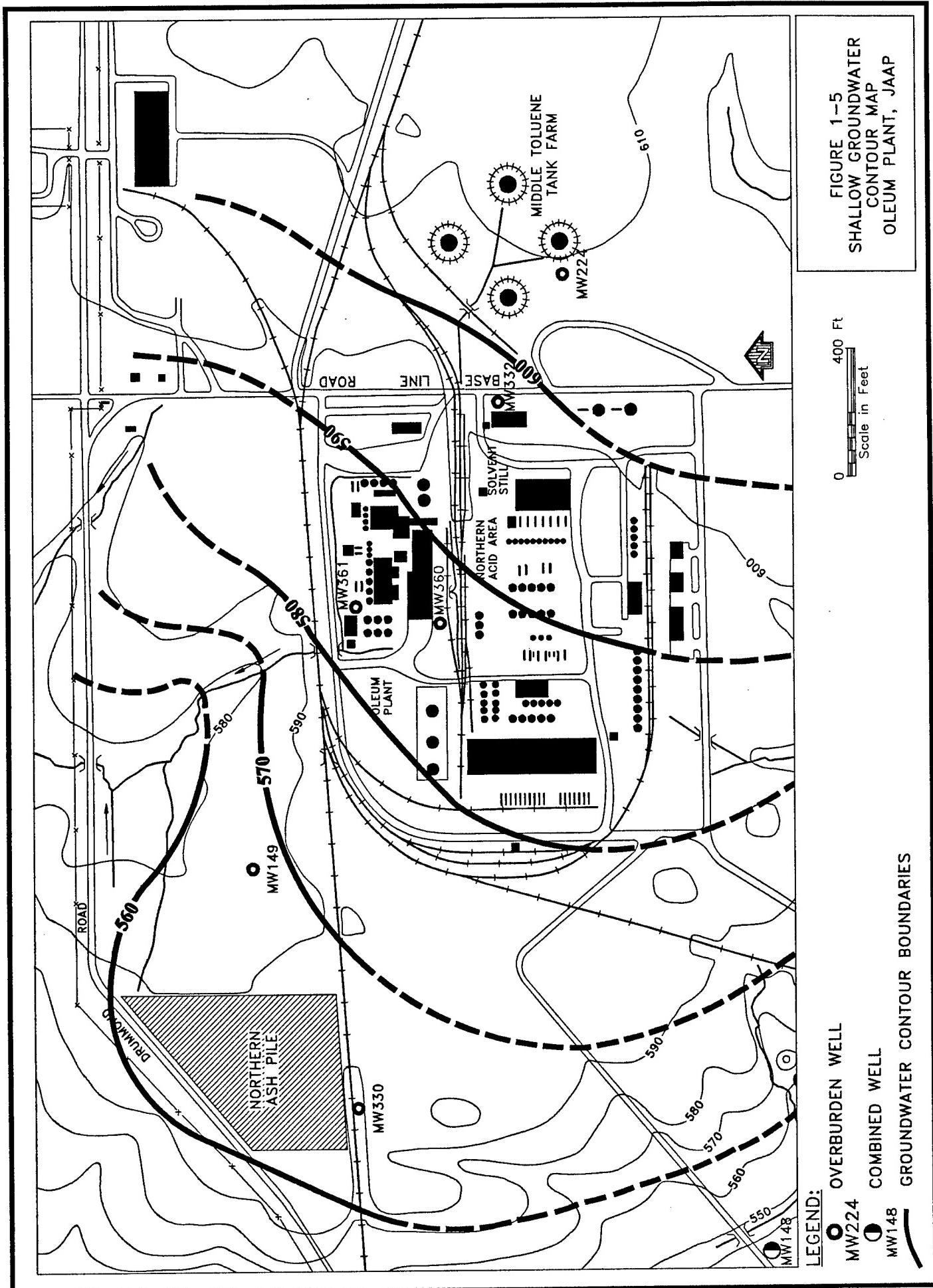


FIGURE 1-3
GEOLOGIC CROSS SECTION A-A'
OLEUM PLANT - MFG AREA



lithologic logs of nearby water supply well 10 (WSW 10), this glacial drift unit extends to the bedrock interface, which is estimated to be 40 to 50 feet below ground surface. Shallow bedrock is composed of Silurian dolomite similar to that encountered plant-wide (see Section 3.3 of the PH2 RI, Dames & Moore, 1993).

Based on water level measurements taken during the field investigation, the water table in the Oleum Plant lies approximately 5 feet below ground surface. While regional information suggests that groundwater in the area flows westerly, the local influence of the Jackson Creek tributary to the northwest draws groundwater in a north-to-northwesterly direction across the site (Figure 1-5). Using water level measurements from wells MW360 and MW361, located within the Oleum Plant, a northerly gradient of 0.016 is calculated. Using measurements from wells MW149 and MW224, located southeast and northwest of the plant, a northwesterly gradient of 0.018 is calculated. Rising head slug tests performed on wells MW360 and MW361 during the field investigation provide hydraulic conductivity values of 4.0×10^{-5} centimeters per second (cm/sec) and 1.9×10^{-5} cm/sec, respectively. Appendix A presents the plotted data from these tests. Using the average of these two values, the hydraulic gradient across the site of 0.017, and a porosity of 35 percent, the average velocity of groundwater flow in the overburden at the site is calculated to be 1.5 feet per year (ft/yr).



2.0 SAMPLING AND ANALYSIS PLAN

The VOCs 1,1-dichloroethane and 1,1,1-trichloroethane were detected in a groundwater sample, and water-soluble sulfate contamination was detected in groundwater and soil samples collected from the Oleum Plant during the PH1 RI. To evaluate appropriate site remedial alternatives, it is necessary to confirm the presence of VOC groundwater contamination and to locate its source. This will be accomplished by conducting a soil gas survey, resampling six existing wells, and collecting four soil samples. A summary of the proposed field investigation is provided in Table 2-1. The Quality Assurance Project Plan (QAPP) and Health and Safety Plan (Dames & Moore, 1991) prepared for the MFG and LAP Area RIs will be used in this investigation. Both documents are incorporated into this plan by reference.

2.1 SOIL GAS SURVEY

The purpose of the proposed Oleum Plant soil gas survey is to determine the potential source area or areas of the VOCs detected in groundwater at MW360. The soil gas survey will be used as a reconnaissance method, to gather information about soil gas conditions over a large area upgradient of monitoring well MW360, shown in Figure 2-1. Survey data will be used to generate contour lines depicting the concentrations of VOCs detected, which will be used to determine the potential source area of the VOCs detected in groundwater. Based on this information, additional RI activities may be warranted.

2.1.1 Soil Gas Survey Grid Location

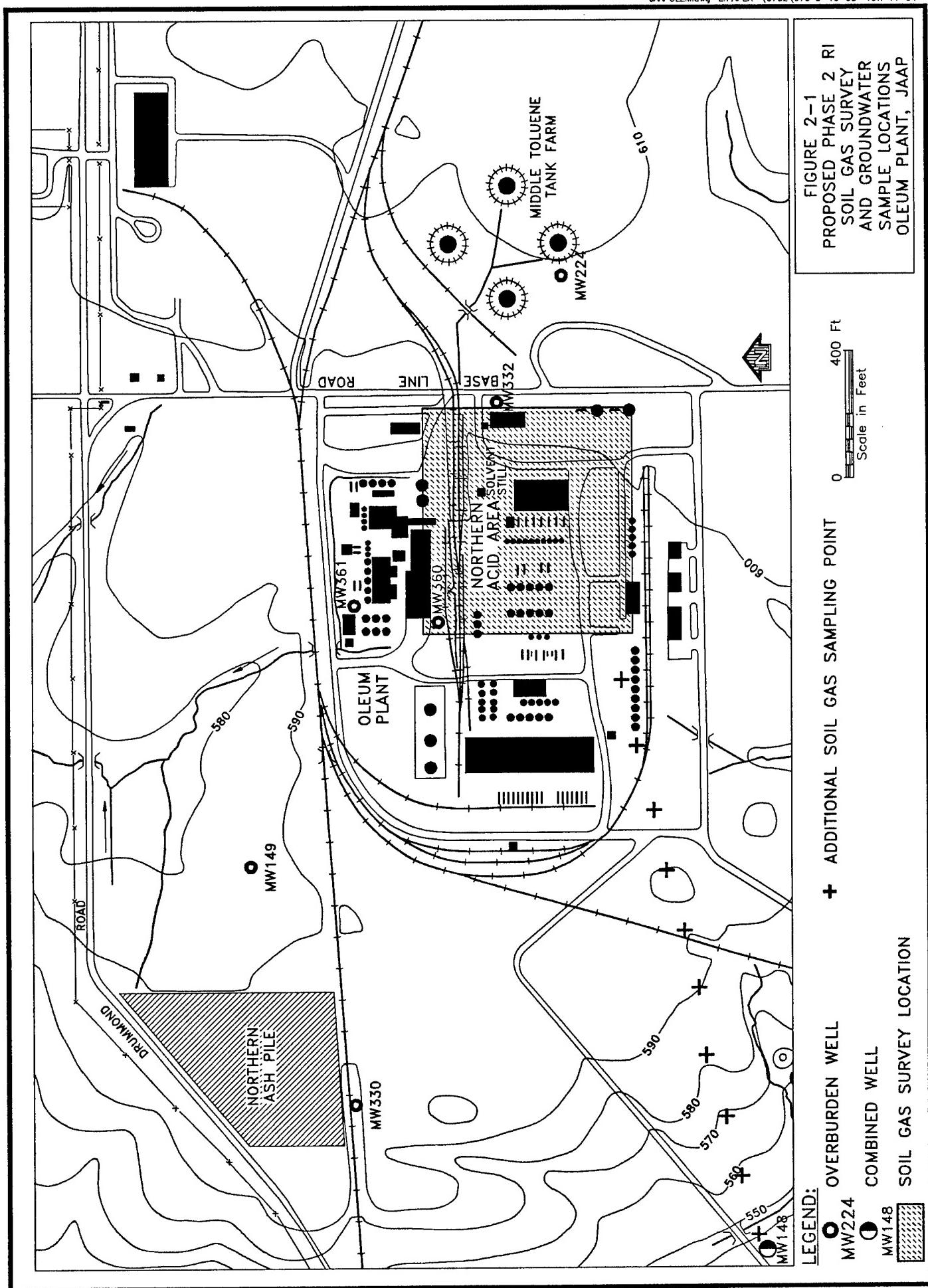
The soil gas survey grid is selected to provide soil gas data at, downgradient of, and upgradient of monitoring well MW360, and upgradient of monitoring well MW148. Because groundwater in the vicinity of the Oleum Plant flows to the northwest, any potential source of the VOCs detected at MW360 must be located at or southeast of this well. Additionally, the constituents of concern were not detected in upgradient well MW224, which is located southeast of MW360 in the Toluene Tank

TABLE 2-1
Summary of Proposed Phase 2 RI Sampling Program
Oleum Plant, Joliet Army Ammunition Plant

MEDIA	TOTAL SAMPLES	SAMPLE ID	DEPTH (ft) OR AQUIFER (a)	ANALYTE		FIELD QC SAMPLES	
				SULFATE (b)	VOLATILES	FIELD DUPLICATE (c)	TRIP BLANK (d)
Soil	4SC	OPSC27 A,B OPSC28 A,B	0,2.5 0,2.5	X X	—	—	—
Groundwater	6M/W (existing)	MW148 (Area 8) MW149 (Area 9) MW332 (Area 10) MW330 (Area 9) MW360 (Oleum Plant) MW361 (Oleum Plant)	C U U U U U	X X X X X X	X X X X X X	— — — — — —	— — — — — —
Soil Gas	UP TO 230	To be assigned in the field.	1.5	—	X	(e)	(e)

NOTES

- (a) – Aquifer designation
 - U = glacial drift aquifer
 - C = combined glacial drift/shallow bedrock aquifers
- (b) – Analysis for water soluble sulfate
- (c) – Field duplicates collected at rate of one per 20 samples per medium
- (d) – One tripblank will be submitted per cooler containing aqueous VOC samples.
One tripblank is anticipated to be needed.
- (e) – Soil gas survey QC Procedures are discussed in Appendix A.



Farm, upgradient of the Oleum Plant and the Northern Acid Area. Based on this information, the potential source of the detected VOCs appears to be in the eastern section of the Northern Acid Area, upgradient of monitoring well MW360. Therefore, the soil gas survey will investigate primarily the southeastern section of the Northern Acid Area. This area is also upgradient of monitoring well MW148 and will encompass the solvent still. Data gathered during the soil gas survey should indicate whether the VOCs detected at MW148 and MW360 are derived from the still or another common source.

2.1.2 Soil Gas Survey Grid Size

The 455,000-square-foot soil gas survey grid (650 by 700 feet) will have sampling points at 50-foot intervals, which will result in 210 sampling points. An additional 10 sampling points will be collected along a line from the southwest corner of the grid to well MW148 (using 200-ft spacing) to evaluate any relationship between the VOCs in well MW360 and those in MW148. Four additional sampling points will be located in the immediate vicinity of the still, and up to six sampling points will be available for placement at identified potential source areas that are not located at grid sampling points. Therefore, completion of the soil gas survey may involve collection of up to 230 soil gas samples.

2.1.3 Soil Gas Survey Method

A PETREX passive soil gas survey will be performed at the Oleum Plant by the Northeast Research Institute, Inc. (NERI). PETREX is appropriate for use at the Oleum Plant because it can identify individual VOCs in soil gas and their relative concentrations, including trichloroethanes and dichloroethanes. This method can detect several parts per billion (ppb) of VOCs in soil gas released from groundwater. Passive soil gas survey sample units may remain underground for variable periods, depending on project needs and site conditions. Extended collection intervals (days to weeks) provide results that limit false-negatives and increase detection efficiency. Additionally, because of the extended collection interval, passive soil gas surveys can monitor soil gas conditions in less permeable soil, including clays. At the Oleum

Plant, soil is primarily clays and clayey sands; the total VOC concentration detected in groundwater at MW360 was less than 10 ppb. Therefore, a passive technique is considered to be the appropriate soil gas survey methodology for the Oleum Plant. A complete discussion of the soil gas survey protocols is provided as Appendix A of this document.

2.2 GROUNDWATER SAMPLING PROGRAM

Two VOCs and water-soluble sulfate have been identified as potentially site-related contaminants in groundwater at the Oleum Plant. The PH1 RI indicated that two VOCs--1,1-dichloroethane and 1,1,1-trichloroethane--were present in groundwater at monitoring well MW360. The same VOCs were detected at MW148 during the MFG PH2 RI, and both wells are downgradient of portions of the Northern Acid Area. Existing wells in the vicinity of the Oleum Plant and the Northern Acid Area will be resampled to confirm the presence and define the extent of VOCs and water-soluble sulfate in groundwater. The additional groundwater and soil gas survey data will be used to determine whether a large plume of VOCs exists at the site. Additional wells will not be installed for this investigation. The locations of the existing wells that will be sampled are included in Figure 2-1.

To evaluate groundwater conditions in the vicinity of the Oleum Plant, six existing monitoring wells (MW148, MW149, MW332, MW330, MW360 and MW361) will be resampled and analyzed for VOCs and water-soluble sulfate. As shown in Figure 2-1, MW332 is located in Area 10, the Central Toluene Tank Farm, and will be sampled to monitor site-specific upgradient conditions. MW149 and MW330 are located in Area 9, the Northern Ash Pile; sampling of these will aid in monitoring downgradient conditions. MW148 is located west of the Oleum Plant and the Northern Acid Area, in Area 8, and will provide additional information about downgradient groundwater conditions.

All six wells will be sampled using dedicated bailers; the resultant unfiltered samples will be sent to a USAEC-certified laboratory. The samples will be analyzed for VOCs according to EPA Method 624 and USAEC Method UM20, and for water-

soluble sulfate according to EPA Method 300 and USAEC Method TT10. A complete discussion of applicable sampling and shipping procedures, including sample containers, preservation, and holding times, is presented in SOPs C.1, C.7, and C.8 in Appendix B. A detailed explanation of analytical methods is contained in the QAPP (Dames & Moore, 1991).

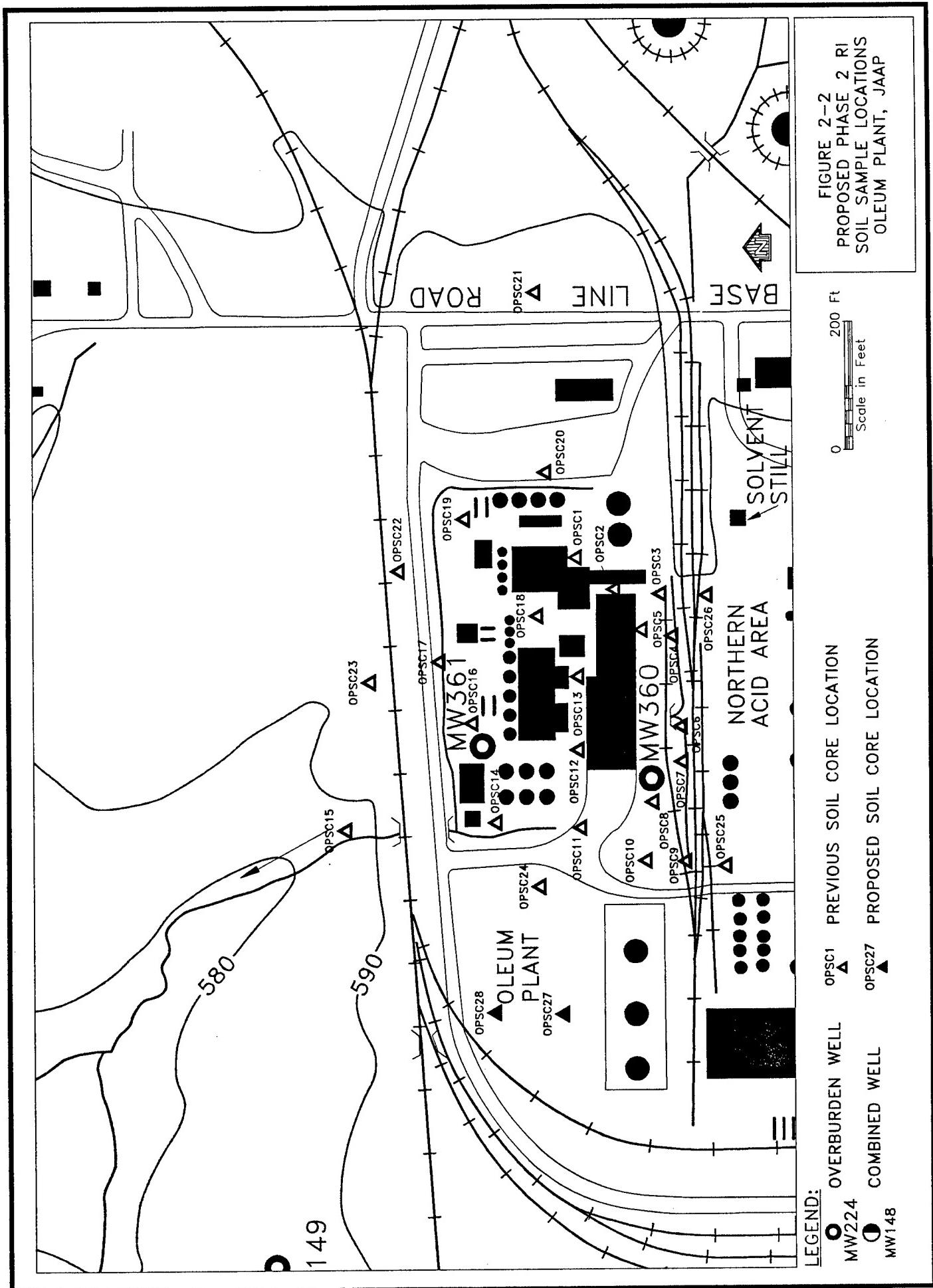
2.3 SOIL SAMPLING PROGRAM

The purpose of the proposed Oleum Plant soil sampling is to define the extent of water-soluble sulfate contamination in site soil. A total of 68 soil samples from 26 locations were collected during the Oleum Plant PH1 RI and analyzed for water-soluble sulfate. Four additional soil samples from two locations will be collected and analyzed for water-soluble sulfate during the Oleum Plant PH2 RI. The locations of the previous and proposed samples are shown on Figure 2-2.

Soil data from the PH1 RI were used to delineate soil contamination in the vicinity of the Oleum Plant; however, data were insufficient to delineate the western extent of contamination. Therefore, two soil cores (OPSC27 and OPSC28) will be collected approximately 200 feet west of PH1 RI soil core OPSC24. Soil core OPSC27 will be collected 120 feet north of the middle of three above-ground storage tanks, and OPSC28 will be collected 100 feet north of OPSC27. Samples from each location will be collected at depths of 0 and 2.5 feet. (Detailed soil sampling procedures are outlined in SOP C.3 in Appendix B.) All samples will be analyzed for water-soluble sulfate by USAEC Method KT05/EPA Method 300 (see QAPP (Dames & Moore, 1991)). For information concerning sample containers, preservation, and holding times, refer to SOP C.7 in Appendix A.

2.4 QA/QC PROGRAM

All activities conducted during the implementation of this Technical Plan will be in accordance with the QAPP (Dames & Moore, 1991), which incorporates all quality assurance/quality control (QA/QC) elements in accordance with EPA guidance (USEPA, 1988) and the Installation Restoration QA Program (IRQAP) (USATHAMA, 1990).



During the PH2 Oleum Plant sampling program, one duplicate water sample and one trip blank sample will be collected. These samples are consistent with the QAPP (Dames & Moore, 1991) and are included in Table 2-1. The groundwater duplicate sample is proposed to be collected from monitoring well MW360.

The soil gas survey has a separate QA/QC program, which is discussed in the NERI Technical Plan, Appendix A of this document.

2.5 OTHER ACTIVITIES

2.5.1 Decontamination Procedures

USAEC decontamination procedures for soil gas sampling equipment (trowels, augers, and other tools) will be followed, as outlined in SOP C.5 in Appendix B. Dedicated bailers will be used for groundwater sampling; therefore, decontamination procedures do not apply to the proposed groundwater sampling methodology.

2.5.2 Water Level Monitoring

Groundwater levels in the six wells near the Oleum Plant will be measured at a selected single day interval during the PH2 RI field program. Water level data will be used to define groundwater flow direction and to calculate groundwater and contaminant migration rates. Groundwater measurements will be conducted in accordance with the methods specified in SOP C.9, Appendix B.

3.0 REPORTING

If a source area of VOCs is identified, additional RI activities such as soil sampling and the installation of additional monitoring wells may be recommended as appropriate. In the event that such contingency sampling is required, a sampling program will be generated as an amendment to this plan. This approach is proposed in order to facilitate the rapid collection of data without the need for generating new FSP which would be considered to be a Primary Document in the FFA.

Following analysis of the chemical and other data, a comprehensive PH2 RI report will be prepared for the Oleum Plant. This report will be presented as an addendum to the JAAP MFG RI. It will be submitted to EPA and IEPA in Draft, Draft Final, and Final versions. An internal draft will be submitted to USAEC for review prior to finalizing the Draft version.

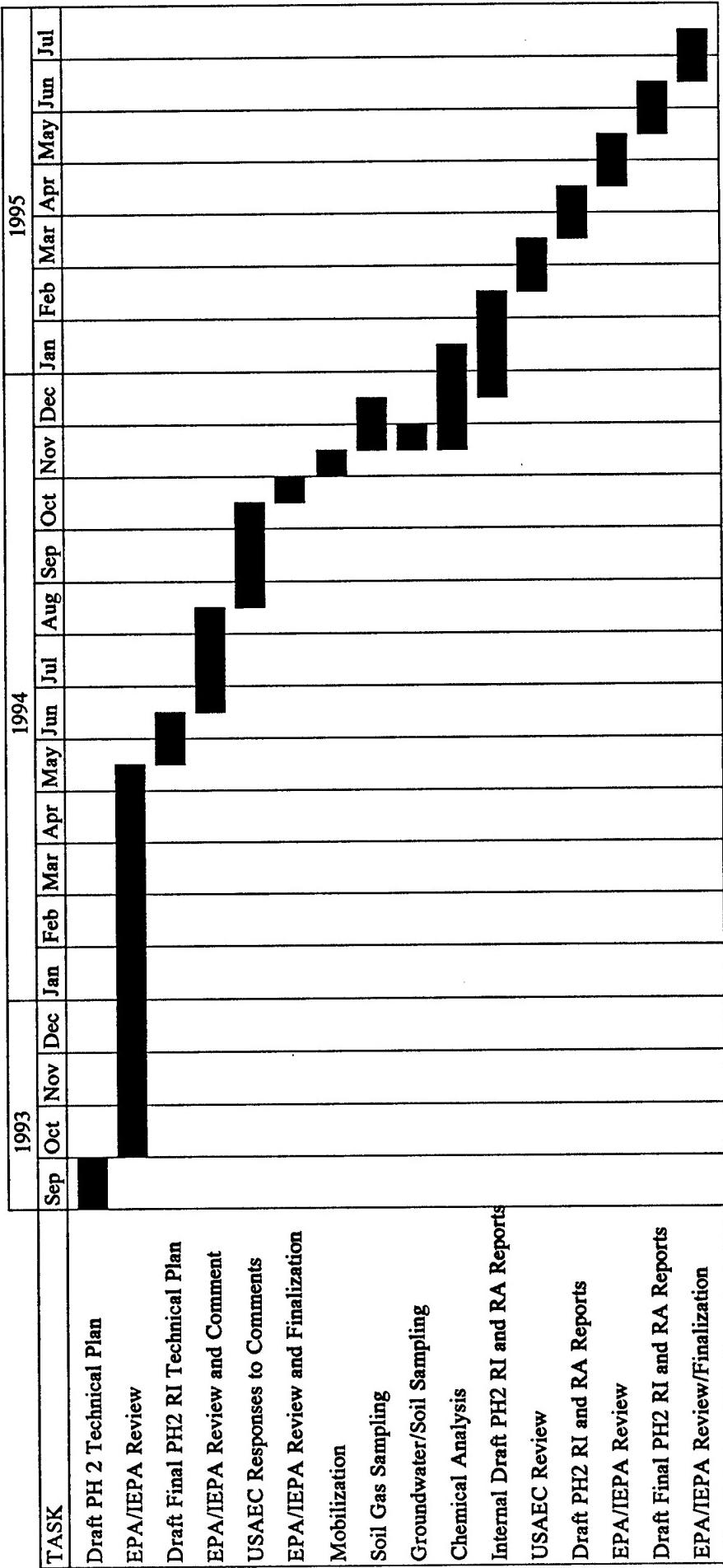
The RI report will contain a summary and interpretation of the data gathered during implementation of the Technical Plan. Data analysis and presentation in the report will include: (1) an evaluation of VOC concentrations in soil gas and groundwater in the vicinity of the Oleum Plant; (2) maps showing soil gas VOC concentrations contours and VOC plumes in groundwater, if any; and (3) an evaluation of the degree and extent of contamination.

4.0 SCHEDULE

The schedule for the individual tasks to be performed for completion of the Oleum Plant PH2 RI is presented in Figure 4-1. This schedule illustrates work to be performed and key milestones.

FIGURE 4-1

SCHEDULE FOR THE OLEUM PLANT
PHASE 2 RI



NOTES:

RI = Remedial Investigation

RA = Risk Assessment

Assumes no contingency sampling is required.

5.0 REFERENCES

- Dames & Moore, 1993. Phase 2 Remedial Investigation, Manufacturing Area, Joliet Army Ammunition Plant, Joliet, Illinois, submitted to the U.S. Army Environmental Center, Report No. ENAEC-IR-CR-93065.
- Dames & Moore, June 14, 1991. Quality Assurance Project Plan, Remedial Investigations/Feasibility Studies, Manufacturing Area and Load-Assembly Package (LAP) Area, Joliet Army Ammunition Plant, Illinois, submitted to the U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland.
- T. Erdman, personal communication. Mr. Erdman, JAAP Operations Manager, provided a brief, undated outline of the oleum manufacturing process. The outline's author is unknown.
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APPENDIX A:
Standard Operating Procedures for the
PETREX Environmental Soil Gas Survey

**STANDARD OPERATING PROCEDURES
FOR THE PETREX ENVIRONMENTAL SOIL GAS SURVEY
TO BE CONDUCTED AT THE
JOLIET ARMY AMMUNITION PLANT (JAAP)
IN JOLIET, ILLINOIS**

**Prepared for:
Dames and Moore**

**Prepared by:
Mark H. Hatheway
Manager of Environmental Operations**

August 1993

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QUALITY ASSURANCE PROGRAM OVERVIEW

Corporate Structure

Northeast Research Institute, Inc. (NERI) provides a range of environmental services that are organized into two distinct business lines:

- PETREX Passive Soil Gas Surveys
- Industrial Hygiene and Analytical Lab Services

The Company maintains two laboratory/project facilities. All analytical and project services are conducted in the corporate headquarters located in Farmington, Connecticut. The Lakewood, Colorado facility conducts PETREX Passive Soil Gas analyses and related project services.

Due to physical separation of NERI's facilities and the specific requirements for quality control and assurance dictated by the two services, quality assurance programs for each business line developed by the corporation are administered by local management, under the guidance and overall approval of NERI's V.P. of Operations and President. NERI's corporate quality assurance plan encompasses the basic procedures that are included in detail in the individual product line quality assurance plans sections herein. At a minimum the following items are included as company-wide requirements:

- Sampling protocols
- Chain of Custody and sample tracking documents
- Analytical protocols
- Instrument calibration of maintenance
- Procedure documentation and oversight
- Data analysis procedures
- Data processing validation and cross checking
- File assembly and maintenance
- Technical oversight and review by management
- Data and file archiving
- Sample and waste disposition

These standard procedures assure consistent work flow, minimize the occurrences of inaccuracies or unclear data reporting, and provide numerous check points to identify any problems as they develop.

**STANDARD OPERATING PROCEDURES FOR THE PETREX ENVIRONMENTAL SOIL
GAS SURVEY TO BE CONDUCTED AT THE JOLIET ARMY AMMUNITION
PLANT IN JOLIET, ILLINOIS**

1.0 PURPOSE OF THIS DOCUMENT

The steps and information contained herein are the Standard Procedures for carrying out the PETREX environmental soil gas survey at Joliet Army Ammunition Plant in Joliet, Illinois.

If any questions arise upon review of this document, please address your questions to NERI's technical staff. Please call:

Mark H. Hatheway, Corporate Project Operations Manager
Northeast Research Institute, Inc. (203) 677-9666
309 Farmington Avenue, Suite A-100, Farmington, Connecticut 06032

-OR-

Paul A. Harrington, Regional Project Operations Manager
Northeast Research Institute, Inc. (303) 238-0090
605 Parfet Street, Suite 100, Lakewood, Colorado 80215

2.0 OVERVIEW OF MANAGEMENT CONTROLS

The PETREX Passive Soil Gas Survey system includes multiple steps, some of which are proprietary, due to the patented nature of the technique. The steps of the process include: manufacture and assembly of the soil gas samplers, field installation and retrieval of the soil gas samplers, laboratory analysis by Mass Spectrometry and Gas Chromatography/Mass Spectrometry, interpretation of results, and production of the final report on the soil gas survey which includes compound and mixture isopleth maps. Each operation has its own set of procedures and quality control steps. With these multiple operations, NERI has made serious efforts to staff each of these operations with personnel qualified for the job duties assigned. Manager level personnel oversee and supervise the use of documents as set forth in individual procedural documents. It is beyond the intent of this document to supply every detail of the multiple operations; emphasis is placed on

the type of information that allows the reader to understand the basic operations of sampler production, field operations, analysis, and reporting of data. NERI's managers must approve the data analysis and report by countersignature prior to releasing any data to the client.

2.1 Staff Qualifications

NERI's professional staff includes computer specialists, chemists, geologists, and environmental scientists. New staff members are selected based on their educational background and work experience, as required to successfully fulfill their function within the company. In-house training is provided to all new personnel for a minimum period of two weeks. The mass spectrometer operators receive additional training by the instrument(s) manufacturer as required. Personnel that will be performing field work are trained for working on hazardous waste sites. This training is performed by sending field personnel to outside courses; at a minimum they receive the 40 hour Health & Safety course (with a yearly 8 hour refresher) that complies with the OSHA requirements of 29 CFR 1910.120 (e) (3) (i).

3.0 PRODUCTION OF PETREX SOIL GAS SAMPLERS FOR USE AT THE JAAP

3.1 Charcoal Bonding

PETREX collection wires shall be prepared by applying pre-sieved activated charcoal to the tips of ferromagnetic wires. The resultant collection wires shall contain size-sorted activated charcoal bonded to the wire within 1 inch of the tip. The collector wires selected for this process shall have a Curie point of 358°C.

3.2 Sampler Tubes

Commercially available glass culture tubes, measuring 25 mm X 125 mm and having a screw cap closure, will be prepared by hand washing, washed in a commercial dishwasher, rinsed in methanol, and baked in an oven at 180°C for one hour.

3.3 Cleaning of Collector Wires

The charcoal bonded ferromagnetic wires shall be cleaned by heating in a special high vacuum apparatus at 358°C for 12 minutes. Wires will be cleaned in lots of 30. The 30 wires shall be sealed in one clean culture tube under an inert atmosphere, assigned a lot number, and the lot(s) placed in inventory.

3.4 Lot Release and Repackaging

3.4.1 Quality Control and Quality Assurance

Prior to releasing inventory lots for the soil gas survey at the JAAP, two collector wires from each lot shall be tested for cleanliness and adsorption potential. One wire will be analyzed by mass spectrometry without exposure ("as is"), to verify that the lot is clean. The second wire shall be exposed to tetrachloroethene (PCE) or trichloroethene (TCE) vapor for six seconds, and then analyzed in order to verify that the charcoal is highly adsorptive. Exposures shall be conducted in a hood, in a laboratory separated physically and by ventilation from the storage and analysis of Petrex samplers.

3.4.2 Repacking for Shipment to the JAAP

Prior to shipment to the JAAP, approved lots will be removed from inventory, and the collector wires will be repackaged in pre-cleaned sampler tubes under an inert atmosphere. From each lot containing 30 collector wires, 12 sampler tubes shall be packaged with 2 collector wires and 2 sampler tubes with 3 collector wires. The basis for having 2 wires in a tube is that it allows NERI to analyze one wire by standard Thermal Desorption-Mass Spectrometry (TD-MS), with the second wire retained as a back-up or used later for analysis by Thermal Desorption-Gas Chromatography/Mass Spectrometry (TD-GC/MS). The third

collector wires shall be used for the mass spectrometer set-up and gain adjustment procedure that will be performed for this survey.

Repackaged tubes with 2 and 3 collector wires shall be assembled into batches of 25 sampler tubes with either 2 or 3 three-wire tubes in each batch. The batches shall be held in inventory, with the unique inventory number (dated) until release for the JAAP project.

3.5 Custody Document

A Chain of Custody Document accompany the samplers released to the field for the JAAP project.

This document shall accompany the PETREX sampler tubes through all transportation, field, analysis, and disposal steps.

4.0 PETREX FIELD OPERATIONS

The procedures described below reflect the steps that NERI staff shall perform. Some flexibility will be allowed in the field to adjust for unusual site conditions; however NERI field personnel shall discuss any alterations in the planned project with a NERI Project Operations Manager, Dames and Moore, and the client project manager before making any changes to an approved work plan. Changes shall be documented in a project notebook.

4.1 Locating Sampler Sites

Sampler placement sites shall be predetermined on the accepted survey work plan and will be located from a nearby, surveyable landmark using a compass and pacing, or some other measuring device (e.g., measuring wheel, hip chain, or tape measure).

4.2 Soil Coring

Once a sampler site has been established, a hole shall be cored to a depth not to exceed eighteen (18) inches (sampler placement depth shall be held constant for this survey). The coring will be accomplished using a variety of tools depending on the nature of the material to be cored. The holes shall be vertical and as free from debris as possible. When sampling is performed in areas covered by asphalt or concrete, a electric-powered rotary hammer drill with a carbide-tipped bit is used to drill a 1-1/2 inch diameter hole in the cover.

Down-hole tools are decontaminated between each boring by following the procedure outlined in Section 4.9 below.

4.3 Sampler Placement

Immediately after the hole is cored, a soil gas sampler tube shall be removed from the storage bag and the bag be resealed. The cap will be removed from the tube, and the tube placed vertically, open end down, into the hole. Clean galvanized wire may be attached the tube for ease in later retrieval. The opening of the hole shall be plugged with aluminum foil, with soil or sod placed on top of the foil to bring the hole back to grade. The sampler cap shall be placed in a clean storage bag to be used again later during sampler retrieval.

Samplers placed under asphalt or concrete will be treated the same as those in uncovered soil, except for modifications to permit easy retrieval and to avoid potential down-hole contamination from surface cuttings. To retrieve the samplers, a length of 18 gauge galvanized steel wire may be twisted around the neck of the tube and run to the surface so that the tube may be recovered by pulling on the retrieval wire. An aluminum plug shall be then placed near the top of the hole, and the remainder of the hole be plugged with quick setting hydraulic cement.

4.4 Sampler Location Marking

Each sampler location position shall be flagged using pin flags, spray paint or ribbon flagging, then the location marked and numbered on a base map. A bound field notebook will be used to record the date, sampler number, sampler location description, soil type, and general observations.

4.5 Special Use PETREX Samplers

This PETREX survey will include samplers that monitor the field exposure time period (referred to as "time calibration samplers"), and others that monitor the integrity of the shipment ("travel blanks").

A series of time calibration samplers shall be included as part of this survey. These samplers will be placed in an area of known or suspected contamination. Time calibration samplers will be retrieved and analyzed at specified time intervals to determine the appropriate field residence time for the survey. A dedicated form shall be used when submitting time calibration samplers to NERI's laboratory. These time calibration samplers shall be analyzed within one day of receipt in the laboratory, so that the length of exposure for the entire survey can be rapidly ascertained and communicated to field personnel.

A minimum of two travel blank samplers shall be included for the PETREX survey at the JAAP. The travel blanks shall remain unopened through all transportation steps in order to monitor for potential contamination acquired during transit. The travel blanks will be returned with the survey samplers, with notations made as to the number of travel blanks submitted. Travel blanks shall be analyzed concurrently with the survey samplers.

4.6 Sampler Retrieval

All samplers from this survey shall be retrieved when analysis of the time calibration samplers indicates that there has been sufficient loading of gases onto the charcoal absorbent. The steps in the retrieval process will be as follows: (1) Soil will be gently excavated until the tube is exposed. (2) A cap will be taken from the sealed storage bag. The Viton seal will be checked to

make sure it is seated inside the cap. (3) The sampler tube will be removed from the hole, and any dirt that is on the threads of the tube will be wiped off with a clean cloth. If the tube is broken or cracked, the collector wires shall be transferred to a new tube using forceps. (4) The tube will be capped tightly, numbered (see Section 4.7), and placed in a storage bag. (5) Bore holes shall be filled or patched as required by Dames and Moore and JAAP personnel. (6) Flagging material and any other debris shall be removed from the survey area.

4.7 Sampler Numbering

Each sampler tube shall be immediately numbered according to the scheme established in the field notes and on the base map. The location number shall be written on an adhesive label which is applied to the tube cap. Labels shall be pre-numbered before starting the survey retrieval process, to ensure that no two sampler locations have the same number. Field staff shall supply notations regarding the site conditions and the condition of samplers when retrieved.

4.8 Sampler Shipment

Once all samplers have been retrieved, they will be sealed in storage bags, wrapped in bubble packing material, and packed tightly in a box for shipment. (Packing materials such as Styrofoam, vermiculite, or newspaper can introduce contaminants, and therefore must not be used for packaging.) The samplers, field notes, base map, chain-of-custody document, and the sample submittal form shall be either hand-carried or shipped by overnight courier service to NERI's laboratory.

4.9 Decontamination of Equipment and Tools

All down-hole equipment and tool parts which contact excavated soil shall be constructed of heavy gauge steel. These tools shall be decontaminated between use at each sampling location by rotation through a four step cleaning process. The steps will be:

1. Immersion and vigorous scrubbing in a solution of laboratory grade detergent until all visual accumulations of soil are removed.
2. Thorough rinsing with distilled water.
3. Spray rinsing with methyl alcohol.
4. Air drying.

All derived liquids (and sediment) shall be contained in dedicated vessels supplied by Dames and Moore or JAAP representatives and disposed of by Dames and Moore or JAAP representatives.

5.0 PETREX SAMPLER LABORATORY ANALYSIS PROCEDURES

5.1 Sampler Receipt and Preparation

5.1.1 Incoming Inspection

The laboratory supervisor or trained delegate shall open the box(es) containing PETREX samplers, and verify that the samplers are received in good condition, are suitable for analysis, and that the Sample Submittal Form and other paperwork is properly completed. The sample number on each tube shall be recorded and any missing or duplicated numbers shall be noted. (A missing number may indicate that the sampler could not be retrieved. Samplers with identical numbers generally cannot be analyzed unless their true site location can be established.) If there are any discrepancies, the laboratory supervisor shall place the project "on-hold" until problematic issues are resolved.

5.1.2 Holding Time

Exposed PETREX soil gas collection wires contain a minute quantity of various volatile and semivolatile organic compounds sorbed onto activated charcoal; the protective glass tube is effectively sealed when the Viton-lined cap is seated properly.

Maximum holding time is a function of both the chemical stability of the sorbed compounds, and the integrity of the seal on the tube.

It has been NERI's experience that PETREX soil gas samplers that are properly packaged after retrieval from the field, and stored under environmentally controlled conditions, typically remain compositionally unchanged for at least four months. Even with this long term stability, it is NERI's practice to analyze all samplers within three weeks of receipt of samplers in the laboratory.

5.1.3 Separation of TD-MS and TD-GC/MS Collection Wires

One collection wire shall be removed from each tube using tweezers and inserted into an analytical crystal, and be placed in a second tube and sealed, and a label identical to that on the original tube placed on the cap. The original tubes shall be resealed and stored for possible TD-GC/MS analysis. The wire in the crystal is ready for TD-MS analysis.

5.2 TD-MS Analysis

5.2.1 Instrumentation Used to Analyze PETREX Samplers

Thermal desorption will be accomplished using a Fisher radio frequency power supply and a Curie point pyrolyzer connected to an inlet designed by NERI and Extrel. The mass spectrometer used is an Extrel Spectrel C-50 quadrupole mass spectrometer. The analysis will be controlled and recorded by a 486 DX33 computer with a 320 MB hard drive. Data shall be archived on disk and on 3.5" diskettes. Data shall be kept in perpetuity.

5.2.2 Calibration

5.2.2.1 Recordkeeping

All daily instrument calibration steps shall be printed out and kept in a 3-ring binder near the instrument. The date and all details of the calibration procedures shall be recorded by the mass spectrometer operator.

5.2.2.2 Perfluorotributylamine Tuning

Mass assignment and resolution shall be manually adjusted using a Perfluorotributylamine (PFTBA) standard. The calibration standard may be purchased from Scientific Instrument Services, Ringoes, New Jersey, phone (908) 788-5550. This standard is produced by 3M, and is repackaged and sold to NERI under Product Code FC-43-Perfluorotributylamine. NERI maintains the specifications, product number, and supplier identification in the maintenance files for the mass spectrometer.

A linear correction, based on the known spectrum of PFTBA, shall be calculated. This correction shall be applied to a second PFTBA spectrum. If correct mass (M/Z) values are obtained, the operator proceeds to the next tuning step. If not, Step 1 will be repeated until correct masses are obtained.

Peak intensity ratios shall be set from the major peaks in the PFTBA spectrum using the following values:

<u>Mass</u> <u>(M/Z)</u>	=	<u>Spectrum</u> <u>Intensities</u>
69	=	100%
131	=	48% \pm 10%
219	=	51% \pm 10%

Electron energy shall be set to 70 electron volts and emission is set at 12 millamps. All other operating parameters, such as scans and scan range are established in the computer program. These values may be changed only by the laboratory manager.

Tuning shall be performed at the beginning of each day so that the complete survey is analyzed using the same instrument settings.

5.2.3 Instrument Parameters

The mass spectrometer shall be operated with the following parameters.

Vacuum	-	$< 4 \times 10^{-7}$ torr
Ionization Energy	-	70 eV
Ionization Current	-	12.0 mA
Desorption Time	-	8.3 sec
Desorption Temperature	-	358°C
Number of Scans/Sample	-	33
Scan Rate	-	1,000 amu/sec

5.2.4 Mass Spectrometer Analysis and QA/QC

Survey samplers shall be analyzed in random order. All samplers for this survey will be analyzed without interruption, except in the event of instrument failure.

The organic gases adsorbed onto the charcoal will be thermally desorbed, separated according to ion mass, counted, and a mass spectrum of masses from 47 to 267 shall be obtained.

Periodic background analyses will be performed as a QC measure to assure minimal influence from cross contamination. If there are peaks that are not related to atmospheric gases, the supervisor will be notified and corrective action taken as appropriate.

A written sample number record shall be kept during the analysis to prevent accidental cross numbering. The mass spectrometer control program prompts the operator with a warning if a sample number is entered that has already been used. The operator will check the current number, along with the disk storage location of the previously entered number, to resolve the true numbering situation.

5.2.5 Project Identification

The raw data file generated by each analysis is given a unique file name for storage. The NERI project number is the prefix of the data file number.

5.2.6 Maintenance of the Mass Spectrometer

<u>Frequency</u>	<u>Activity</u>
1,000 Analyses	Cleaning of sample introduction area, ion source, and expansion chamber by in-house technicians.

4,000 Analyses Above noted procedures plus cleaning of lenses and quadrupoles.

Annually: Preventive maintenance program conducted by manufacturer's service representative.

5.3 TD-GC/MS

Upon completion of TD-MS analyses, or upon instruction from the client, selected duplicate collection wires set aside as described in Section 5.1.3 above, will be obtained from storage for TD-GC/MS analysis.

Curie-point thermal desorption of PETREX collection wires into the GC inlet shall be accomplished by using a customized, tunable radio frequency (RF) power supply and a Fischer Curie-point Pyrolyzer. The pyrolysis chamber will be surrounded by the tunable RF coil. One PETREX collector wire at a time shall be loaded into the pyrolysis chamber by inserting the wire to a predetermined depth. The power supply will be adjusted such that the field strength generated is sufficient to reach the Curie point of the PETREX wire, thereby allowing the sample to be desorbed from the charcoal contained on the PETREX wire.

The desorbate shall be concentrated by cryofocusing and injected onto the GC by flash desorption. The sample run begins when the cryo trap begins to desorb. Data collection will begin immediately after the air peak elutes.

5.3.1 TD-GC/MS Instrumentation

Thermal desorption will be accomplished by using a Fisher power supply linked to a Tekmar Model 5010 cryofocusing unit, for analysis using a Hewlett Packard 5987 Gas Chromatograph/Mass Spectrometer system. The GC/MS will be computer controlled, using an RTE operating system. Chromatographic columns may include: Standard Applications - J&W DB624, 75m x 0.53mm x 3.0u; Special Applications - J&W DB-5, 60m x 0.25mm x 0.25u

or J&W DB-625 30m x 0.32mm x 0.5u. The column most appropriate for the specific analysis shall be used.

5.3.2 Calibration

5.3.2.1 Record Keeping

All instrument calibration steps shall be recorded in permanently bound logbooks kept in the laboratory. The date and all details of calibration shall be recorded by the GC/MS operator and checked by the supervisor.

5.3.2.2 Tuning

The instrument is tuned at the beginning of each day using 4-Bromofluorobenzene (BFB).

5.3.3 Instrument Parameters

The parameters listed below will be used for standard environmental analyses. Specific targeted analytes may require different columns/conditions.

5.3.3.1 Thermal Desorption and Injection

Desorption Time: 2 x 95 seconds (190 seconds total)

Desorbate Transfer Temperature: 150°C.

Cryofocusing Trap Temperature: 150°C.

Desorbate concentrated on cyro trap and held until injection

Desorbate injection: by thermal desorption

Injection temperature: 300°C for 2 minutes.

5.3.3.2 Gas Chromatograph

Carrier Gas: Helium @ 6 psi head pressure (6.0 mL/Min.
150°C.)
Injection temperature: 250°C.
Oven temperature programs: 35°C for 1 minute; increasing
8°C per minute to 235°C; hold for 8 minutes.
Data Acquisition Delay: 3 minutes.
Total run time: 34 minutes.
Transfer line temperature: 250°C.
Interface is direct to MS source.

5.3.3.3 Mass Spectrometer

Scan rate: 1.07 scans/second
Scan range: 35 to 260 amu.
Source temperature: 200°C.
Electron energy: 70 eV.
Electron emission: 300 uA.
Electron multiplier energy: as per Autotune
specifications for PFTBA.
Spectrometer tuning: Performed and recorded in a
bound instrument log book, using tuning parameters
for BFB listed Table I.

TABLE I
BFB Tuning Parameters

<u>M/Z</u>	<u>Ion Abundance Criteria</u>
50	15-40% of the base peak
75	30-60% of the base peak
95	Base Peak: 100% relative abundance
96	5-9% of the base peak
173	< 1% of the base peak

174	> 50% of the base peak
175	5-9% of mass 174
176	> 95% but < 101% of mass 174
177	5-9% of mass 176

5.3.4 Quality Assurance & Quality Control

5.3.4.1 System Blank

The TD-GC/MS system shall be tuned daily according to the operational parameters described above. After the results of the tuning are verified, a minimum of one system blank shall be analyzed. A system blank will be an analysis in which all procedures are followed, but no sample (i.e. PETREX collector wire) is introduced. A typical system blank reveals a TD-GC/MS peak at a retention time of 12.9 minutes and a molecular weight of 207 atomic mass units (AMU), which corresponds to a known component bleeding off the GC column. If any other unusual compounds are detected, the cause shall be investigated, correction made, and another system blank run prior to analyzing any other samples.

5.3.4.2 Method Blank

A blank PETREX collector shall be used as a method blank for TD-GC/MS analysis purposes. Results from TD-GC/MS analysis of a PETREX blank will be expected to contain some trace contaminants, due to the ubiquitous nature of many contaminants in the laboratory and environment. Thus, it is standard to see trace levels of acetaldehyde, ethanol, 2-propanone, the column bleed compound (described above), and a peak with a retention time of 24.65 minutes (140 AMU) that is a byproduct of the PETREX wire fabrication

process. On occasion ultra low levels of toluene and benzene have been detected on the method blank, perhaps due to low level carryover in the system or to sampling handling. NERI has established a cleanliness standard for method blanks; if exceeded, no further sample analysis shall occur until the cause is investigated and corrected.

5.3.4.3 TD-GC/MS Calibration

Qualitative accuracy and precision are the goals of this step. Purchased standards of a series of commonly observed volatile organic compounds from PETREX surveys were analyzed using NERI's standard conditions for TD-GC/MS. The retention time of these compounds is listed in Table II. These retention times shall be used as an indication of the performance of the GC column.

The accuracy of the mass spectrometer shall be checked daily using the BFB tuning parameters described above.

NERI's quality program, which includes analysis of a system blank, one or more method blanks, daily tuning of the mass spectrometer, and evaluation of the performance of the gas chromatograph, shall all provide assurance that the system is performing to acceptable standards for TD-GC/MS analysis. The analyst shall proceed to analyze project samples only when all quality checks are acceptable. If not, the Laboratory Manager will be notified and sample analysis will stop until the Laboratory Manager approves the system for use.

TABLE II
Retention Time of Standard Compounds

<u>Compound</u>	<u>Retention Time</u>
CHCl ₃	8.35 minutes
C ₂ H ₃ C ₁₃	8.68 minutes
CC ₁₄	8.95 minutes
C ₆ H ₆	9.23 minutes
Trichloroethene	10.17 minutes
C ₇ H ₈	12.24 minutes
Tetrachloroethene	13.20 minutes

5.3.5 Sample Analysis and Data Management

5.3.5.1 Sample Analysis

A PETREX collector wire shall be removed from the sampler tube with tweezers, then inserted to a predetermined depth into the pyrolysis chamber. The system operating parameters shall be verified and recorded in a bound log book that is kept next to the instrument. Parameters recorded routinely will be: NERI project number, laboratory request number, operator name, date, set-up conditions, and any comments that are considered important by the analyst. Sample analysis shall begin using the standard run conditions detailed in Section 5.3.3. Data acquisition will be computerized, with data processing occurring as acquisition is conducted.

The data package of results, with accompanying forms, shall be first evaluated by the GC/MS supervisor, and if acceptable, be delivered to the project manager for review and incorporation of the results into the project report.

5.3.5.2 Data Management

5.3.5.2.1 File Naming

Quality Control data files shall be named according to the quality control process and the date the file was created. The mass spectrometer tuning calibration file for February 18, for example, will be labeled "CO218"; the naming of files shall be standardized in the laboratory. Project data files will be named by giving it the NERI project number, a four digit code unique to the JAAP project.

5.3.5.2.2 Data Archiving

Calibration files and data generated from analysis of project samples shall be stored on the HP 5987 GC/MS computer. At the completion of the project, the files will be transferred to magnetic tape for long term storage. A copy of the directory (file) listing shall be kept with the tape. Tapes will be archived in a cool, dry environment, free from magnetic fields.

6.0 DATA INTERPRETATION AND PRESENTATION

6.1 Quality Control

Experienced project managers shall perform the data review, analysis, and interpretation. Their work shall be reviewed and countersigned by the Project Operations Manager or his specific designee. The V.P. of Operations shall review this project through all stages (including survey design, quotation, data analysis, reporting, and map production). This routine audit has proven sufficient to assure data integrity, maintain presentation consistency, and

provides for a rapid solution if any deviations from standard procedures are uncovered.

6.2 Compound Identification

Individual compounds shall be identified by comparing the mass spectrum that is obtained from the analysis of each sampler collector wire to a library of reference mass spectra. Several thousand pure compound spectra have been developed by the National Bureau of Standards and are available for spectral comparison. NERI has also developed its own library of spectra through headspace analysis of pure compounds using the PETREX process.

In the event that the presence of very complex mixtures masks targeted compounds, the TD-GC/MS process shall be used to enhance identifications. Retention indices (for common VOCs) can be combined with mass spectra for identifications.

6.3 Compound Mapping

6.3.1 Production of Sampler Location Map

A sampler location map shall be created by placing the field base map on a digitizing board and entering each sampler location (and its respective identifying number) as an X-Y coordinate relative to an origin. Alternatively, base maps may be supplied by the client in AutoCAD Version 10 output formats on a diskette. Cultural and topographic features can also be digitized onto the map as reference points. The relative ion counts for each compound will be plotted at the exact sampler locations.

6.3.2 Production of PETREX Isopleth Maps

The process of plotting ion counts of indicator peaks from the compound(s) identified in the soil gas survey is computerized. Thus the summed ion counts from multiple indicator peaks of identified compound(s) shall be matched with the sampler location

on the base map, and the numeric value be plotted. The data shall be contoured, taking into account all other available data, such as geologic setting, soil types, groundwater conditions, type of contaminant, and site history.

The resultant maps will show, per compound or class of compounds, isopleth lines that describe the distribution and relative intensity of soil gas constituents throughout the survey area. Soil gas isopleth maps are useful for interpreting the areal extent of contamination, the location of source areas and relative "hot spots", and the apparent direction of movement of the contaminants.

The entire PETREX process permits the collection, identification and mapping of numerous compounds simultaneously. This information may be used to differentiate multiple compounds and multiple source areas at JAAP.

6.4 Data Presentation in Report Form

Once the data have been compiled, interpreted, and mapped, a report shall be produced for the client's use. Also, isopleth maps shall be finalized and printed using a sophisticated plotter and CAD software. Reports shall be signed by both the assigned project manager and the Project Operations Manager before they are released to the client.

NERI maintains confidentiality of the work it performs for its clients. All employees are trained in this regard. No report or map shall be released to a third party without prior written consent of the client.

6.4.1 Final Storage of Project Files

NERI maintains all project reports and raw data for a minimum of 7 years. Completed project files shall be stored by project number in secure, dedicated storage areas. Duplicate copies of the Final Report will be stored at both of NERI's offices (Lakewood, CO and Farmington, CT) to protect against potential loss due to fire or other events.

7.0 GUIDANCE ON THE INTERPRETATION OF SOIL GAS RESULTS

This section and Section 8.0 are meant for informational purposes only, and are therefore not a part of the standard procedures utilized for performing PETREX soil gas surveys. The intent is to provide NERI's insight on using the data provided during a PETREX survey. In addition, Section 8.0 discusses alternative uses for the PETREX samplers to address site specific questions.

Confirmation and quantification of soil gas results are generally conducted using standard field sampling methods for soil and groundwater analysis. The soil gas maps are used to guide the placement of borings and wells.

In general extreme caution needs to be exercised when trying to extrapolate soil gas results (without the above sampling and analysis) to predict the exact source of the soil gas signal (i.e. soil or groundwater), the depth of the signal, or concentrations of contaminants. In NERI's experience results from soil gas surveys that have been conducted at a uniform shallow depth cannot be used to calculate the depth to the source or the absolute concentration of contaminants at depth.

Ion counts for any compound at one sample location can only be compared to another location within the same survey for the same compound. Ion counts of different compounds cannot be compared to each other. Also, the isopleth maps from one survey cannot be quantitatively compared to the results of any other survey, or between two surveys conducted at the same site at different times of the year. However, the same "hot spots" and migration pathways normally are detected in the same place over multiple surveys at a given site, allowing for migration.

8.0 ADDITIONAL USES OF PETREX SAMPLERS

PETREX samplers have numerous other uses, and the techniques described below are often incorporated into the soil gas survey design. (Specific instructions on sampling, shipment methods, and blanks are provided for each project.)

8.1 Headspace Analysis of Soils and Water

Headspace analysis can be used to establish a mass spectrometric pattern of compounds from soils or water; this pattern can then be used during interpretation of the soil gas survey by searching for the headspace pattern in the results obtained from the soil gas survey. This approach is very helpful for verifying sources or for mapping specific blends of commercial products at a site.

A soil sample is headspaced by collecting approximately 25 grams of soil in a thermochemically cleaned headspace container. A clean PETREX culture tube is often used. The sample is shipped to NERI's laboratory, where several PETREX collector wires are added. The sample is allowed to equilibrate for up to 24 hours. The exposed wires are then removed and prepared for thermal desorption mass spectrometric analysis as described earlier. A similar process is used for screening water samples.

APPENDIX B:
Fieldwork Standard Operating Procedures

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SECTION A
Field Documentation

SOP NUMBER: A.1

DATE: September 1989

TITLE: Field Recordkeeping

SCOPE: This procedure provides guidance for the maintenance of records in the field.

OBJECTIVE: To establish uniform methods of maintaining and preserving records that contain observations, measurements, and other documentation of field conditions.

EQUIPMENT:

- o Sample identification tags (Figure A.1-1).
- o Chain-of-custody (COC) forms and records (Figure A.1-2).
- o Site logbook.
- o Field logbook(s).
- o Field equipment log (Figure A.1-3).
- o Photographic logs.
- o Sample boring log forms (Figure A.1-4).

PROCEDURES:

1. The Project Manager (PM) or another designated person maintains a supply of the documents listed above, including field notebooks. The PM is responsible for the inventory of the documents and the assignment of these documents to specific projects. The sampler maintains a personal field logbook in which is recorded the final disposition of all relevant field information. Documentation in logbooks, sample labels, custody records, and other data sheets must be completed in permanent black ink. Errors are to be crossed out with a single line, dated, and initialed. None of the documents are to be destroyed or discarded. All voided entries will be referenced in the site logbook and maintained in a file that will be kept onsite.

Dames & Moore I.D. No.
FIELD SAMPLE

FIGURE A.1-1
SAMPLE IDENTIFICATION LABEL

A.1-2

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FIGURE A.1-2
CHAIN-OF-CUSTODY RECORD

Other Division: Original Accounting Statement: Copy to Coordinator Field Files

THE STOIX RECORD

Damon & Moore

FIGURE A.1-3

Revision Date: January 1989

1. FIELD EQUIPMENT LOG

Equipment Number _____

Page ____ of ____

Equipment Description _____

1. CALIBRATION

2. CLEANING

3. MAINTENANCE

Personnel Qualified to Operate and Maintain

Reviewed By _____ Date/Time _____
Entries Complete? [Y or N] _____

FIGURE A.1-4
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LOCATION OF BORING		JOB NO.	CLIENT	LOCATION				
		DRILLING METHOD:		BORING NO.				
				SHEET				
		SAMPLING METHOD:		OF				
				DRILLING				
		WATER LEVEL		START TIME				
		TIME		FINISH TIME				
		DATE		DATE				
		CASING DEPTH						
DATUM	SAMPLER TYPE	SURFACE CONDITIONS:						
	metres feet inches covered	DEPTH OF CASING	Sample at depth	BLOW/SFT. SAMPLER	NUMBER OF RINGS	ELEVATION	DEPTH IN FEET	SOIL GRAPH
						0		
						1		
						2		
						3		
						4		
						5		
						6		
						7		
						8		
						9		
						0		
						1		
						2		
						3		
						4		
						5		
						6		
						7		
						8		
						9		
						0		

2. Site Logbook

The site logbook is the master field investigation document and is required for all projects. It is a bound book with hard cover and sequentially numbered pages. ("Bound" in this instance refers to the fact that the pages are glued and/or sewn together within the hard cover. Ring binders or similar binding types do not constitute a bound logbook.) Its primary purpose is to contain within one document the actual field data or references to other field documents that specifically describe each activity that has occurred in the field on any given day. The site logbook also contains any administrative occurrences, conditions, or activities that have affected the fieldwork for any given day or field task. The front of the logbook lists the project number and name and the date(s) of use. The site logbook is kept up to date on a continuous basis.

One site logbook may be all that is required for a project depending on project size, complexity, and number of field personnel/teams (i.e., small projects may require only the site logbook, while large projects may require several additional field logbooks with the site logbook serving as a summary volume).

The site logbook will contain the following information (this is not a comprehensive listing, but indicates the nature, type, or intent of data):

- o Day, date, time entered onsite, temperature, weather conditions, and names and titles of personnel present onsite.
- o Name, title, and affiliation of any visitors who entered the site during the day.

- c Chain-of-custody details to include traffic report, air bill, chain-of-custody form, and sample label/tag numbers; types of samples, laboratories to which samples were sent, etc.
- o Arrival time of any subcontractors onsite, number of feet drilled, total feet of casing installed, screen lengths, number of samples per borehole, number of duplicate samples, number of split samples, laboratory to which split samples were sent, depth of pit or length of trench excavated, and references to field logbook(s) or field forms that contain more specific field information for any of the above tasks.
- o Number of samples by media and any field tests that may have occurred during the day's events, including a reference to the field logbook or the field forms that contain more specific information on all sampling that has occurred.
- o Decontamination iterations, equipment decontaminated, and procedures utilized.
- o Specific comments relative to any problem areas that occurred during the day's activities, their final resolution, and their anticipated impact on the outcome of the field investigation.
- o Instruments calibrated during the day, the individual who performed the calibration, and reference to the page number in the calibration log that provides more specific information on calibration procedures and results.
- o A record of telephone calls (incoming or outgoing) pertaining directly to the decisionmaking process of the field investigation, along with the outcome of each conversation, and a reference to the telephone log to obtain more specific information on the call.

This is a partial list of the types of information to be included in the site logbook. The last item to be entered at the bottom of each page is the signature of the individual responsible for completing the logbook. This person is normally the field supervisor or equivalent individual.

3. Field Logbooks

The requirements for the field logbooks are the same as for the site logbook. In general, these books never leave the site and are sequentially numbered, if more than one is used. The front of the logbook lists the project number and name and the date(s) of use. A field logbook is normally used by the rig geologist or by the head field technical specialist to record specific details of the assigned task when more than one rig or team is operating. Although the field logbook contains the specific field information being collected based on the tasks, the number of the field logbook and page numbers used for a particular day's performance will be referenced in the site logbook, to include a brief summary.

4. Field Equipment Logbook

The purpose of the Field Equipment Logbook (FEL) is to document the proper use, maintenance, and calibration of field testing equipment. Before using field equipment, the field supervisor shall inspect and approve the use of the field testing equipment by initialing the appropriate form in the FEL. The FEL is normally a three-ring binder book into which calibration log sheets are placed for each calibrated piece of equipment. A calibration log sheet shall be maintained for each instrument used onsite and shall be kept in the FEL.

The following items shall be tracked in the FEL:

- o Equipment calibration status

- o Equipment decontamination status
- o Equipment nonconformance
- o Equipment inspection and repair records.

The person using, maintaining, or calibrating field equipment shall document his/her actions in the FEL. Entries shall contain the following:

- o Name and signature of person making entry.
- o Date of entry.
- o Name of equipment and its identifying number.
- o Decontamination status.
- o Nature of work conducted.
- o List of reference of procedure(s) used for calibration or maintenance.
- o Manufacturer, lot number, and expiration date of calibration standards.
- o Names of person(s) conducting work.
- o Measurement results (acceptable or unacceptable).

Entries in the log shall be signed and dated by the person(s) making the entry. Every page in the log will be signed and dated by the field supervisor. This signature reflects his/her review and approval of the validity of the entry.

5. Field Data Record Forms

A number of field forms have been developed for use in recording data taken in the field. Examples of the forms are included in the appendix.

- o Field equipment log.
- o Soil boring log form with explanatory text.
- o Groundwater sampling form (Figure A.1-5).

- o Monitoring well construction log with explanatory text.
- o Well development log (Figure A.1-6).
- o Surface water/sediment sampling form (Figures A.1-7 and A.1-8).
- o Soil sampling record (Figure A.1-9).
- o Instrument calibration log (Figure A.1-10).

Every space on a given form must be completed; blank spaces are not acceptable. If information required is not applicable, the space shall be marked "N/A," but not left blank. All entries shall be made in permanent black ink. These forms are to be recorded and kept in the field in a three-ring binder or equivalent in the same location as the site logbook.

6. Sample Identification

Sample identification tags are distributed as needed to field workers by the PM (or designated representative). Generally, serial numbers are recorded in the project files, the field logbook, and the field data record sheet. Individuals are accountable for each tag assigned to them. A tag is considered to be in an individual's possession until it has been filled out, attached to a sample, and transferred to another individual along with the corresponding chain-of-custody record. Sample identification tags are not to be discarded. If tags are lost, voided, or damaged, the facts are noted in the appropriate field notebook, and the PM is notified.

FIGURE A.1-5

Seq. # _____

GROUNDWATER SAMPLING RECORD

Project Name: _____
 Location: _____
 Sample No.: _____
 Date: _____ Time: Start _____ End _____

Project No.: _____
 Client: _____
 Sampler: _____

Sampling Location Designation: _____

Sampling Method: _____

Sample Parameters: _____

Water Level Observations:

Reference Point: _____
 Casing Stick-Up: _____ feet above/below ground surface
 Well Diameter _____ Depth to Water _____ Depth to Bottom _____

Meter Calibration:

Conductivity Meter - Make and Model #: _____
 Date: _____ Time: _____ Solution: _____
 Reading: _____ Temperature: _____ °C
 pH Meter - Make and Model #: _____
 Date: _____ Time: _____ Solutions: _____
 Reading: _____ Temperature: _____ °C

Sample Readings:

Date: _____ Time: _____
 Conductivity: _____
 pH: _____
 Temperature: _____ °C

Notes and Observations: _____

Sampler's Signature: _____ Date: _____

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WELL FORGING/DEVELOPMENT RECORD

Project Name: _____
 Location: _____

Project No.: _____
 Client: _____

Well Designation: _____

Date(s) of Well Installation: _____

Date(s) and Time of Development: _____

Development Equipment: _____

Static Water Level to TOC

Before Development: _____

24 Hours After Development: _____

Quantity of Water in Well Prior to Development

Standing in Well: _____

Contained in Annulus (assume 30% porosity): _____

pH/Conductivity/Temperature

Before: _____ / _____

During; T₁: _____ / _____

T₂: _____ / _____

After Development _____ / _____

Depth (TOC) to Bottom of Well: _____

Screen Length: _____

Depth to Sediment: Before/After Development _____ / _____

Water Characteristics and Changes During Development

Clarity: _____

Color: _____

Particulates: _____

Odor: _____

Length of Stickup: _____

Quantity of Water Removed/Time for Removal

Incremental: _____ / _____

Total: _____ / _____

Quantity of Mud/Water Lost, Removed, or Added During Drilling/Well Installation: _____

Comments: _____

Field Engr./Geologist/Technician Signature: _____

Date: _____

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FIGURE A.1-7
SURFACE WATER SAMPLING RECORD

PROJECT _____ SAMPLE OR LOG NO. _____
 LOCATION _____ SAMPLER _____
 DATE: (Mo/Dy/Yr) _____ TIME: Start _____ End _____
 SAMPLING LOCATION DESIGNATION: _____
 SAMPLING LOCATION DESCRIPTION (Show Dwg.): _____
 SAMPLING METHOD: Grab/Other(Describe) _____

WATER LEVEL OBSERVATIONS:
 Surface Water Depth: _____ (In./Ft.)

CONDUCTIVITY METER: Extech / YSI Other(Describe) _____

Calibration Technique: Solution/Resistor
 Date: / / Time: _____
 Reading _____ μ mhos cm Temperature _____ °C
 Field Calibration: Time: _____ Reading: _____ mg/L/PPM
 Temperature: _____ °C

pH METER: Extech / / Field Calibration: Date: / /
 Time: _____
 pH4 pH7 pH10

Millivolts _____
 Temp °C _____

Readings: . 1 2 3 4 5

Millivolts/pH _____
 Temp °C _____

Field Calibration, Other (Describe) _____

SAMPLE NO.	TYPE (Analysis Required)	PRESERVATIVE	COOL TO 4 °C

Serial Nos. on Seals or Labels: _____
 No. of Transportation Cases: _____

NOTES AND OBSERVATIONS:

SAMPLER'S SIGNATURE:

DATE / /

SEDIMENT SAMPLING RECORD

PROJECT: _____ SAMPLE OR LOG NO(S): _____

LOCATION: _____ SAMPLER: _____

DATE: (Mo/Dy/Yr): _____ TIME: Start _____ End _____

SAMPLING LOCATION DESIGNATION: _____

SAMPLING LOCATION DESCRIPTION (Show Dwg.): _____

SAMPLING METHOD: Grab/Other(Describe):

SEDIMENT QUALITY DATA:

DEPTH TO SEDIMENT - WATER INTERFACE (Inches): _____

SEDIMENT SOURCE (Stream, Channel, Pond, Puddle or Other): _____

CONSISTENCY (Dry, Solid, Semi-solid, Viscous, Suspension or
Other) _____

COLOR: _____

TEMPERATURE (C): _____

OTHER FIELD MEASUREMENTS:

Sample No.	Type (Analysis Required)	Cool to 4 C
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

SERIAL NUMBERS ON SEALS OR LABELS: _____

NUMBER OF TRANSPORTATION CASES: _____

NOTES AND OBSERVATIONS:

SAMPLER'S SIGNATURE:

DATE: / /

Dames & Moore

SOIL SAMPLING RECORD

Project Name: _____

Location: _____

Date: _____ Time: Start _____

Project No.: _____

Client: _____

End _____

Sampling Location Designation: _____ Sampling Sequence No.: _____

Sampling Location Position, See Plan (or describe): _____

Weather Conditions: _____

SAMPLE NO.							
Time (Military)							
Sampling Method							
Top of Sample Container							
Depth (Feet)							
HNU Meter - Sample Reading							
Explosion Level (%)							
Color (Describe)							
Texture (Describe)							
Soil Classification							
Moisture (dry, moist, wet)							
Other Observations							

Comments: _____

Sampler's Signature _____ Date: _____

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INSTRUMENT CALIBRATION LOG

INSTRUMENT: _____
MANUFACTURER _____
MODEL NUMBER: _____
SERIAL NUMBER: _____
DAMES & MOORE ASSET NUMBER: _____
DATE ACQUIRED OR SERVICED: _____
ORIGINAL OR PREVIOUS CALIBRATION DATE: _____

CALIBRATED BY: _____
(Name of Company/Person)

NOTES ON ORIGINAL OR PREVIOUS CALIBRATION:

CALIBRATION SCHEDULE: (Circle One) Daily Monthly Yearly

MAINTENANCE SCHEDULE: (Circle One) Daily Monthly Yearly

CURRENT CALIBRATION RECORD:

DATE: _____ TIME: _____

TECHNICIAN'S NAME/INITIALS: _____

AFFILIATION: _____

CALIBRATION STANDARD(S) USED: _____

CONCENTRATION(S): _____

PROCEDURE (Describe Briefly): _____

DEFICIENCIES (If Any): _____

CALIBRATION PLOTS OR GRAPHS (Attach, If Any)

SIGNATURES: _____ Technician _____ Laboratory Manager

DATE: _____

SYSTEMS OR PERFORMANCE AUDIT:

AUDIT REPORT: _____

SIGNATURES:

AUDITOR: _____ DATE: _____

QA MANAGER: _____ DATE: _____

7. Chain-of-Custody Forms and Records

- o Because samples collected during an investigation could be used as evidence in litigation, possession of the samples must be traceable from the time each is collected until it is introduced as evidence in legal proceedings. To document sample possession, chain-of-custody procedures are followed.
- o A sample is under custody if one or more of the following criteria are met:
 1. It is in the sampler's possession.
 2. It is the sampler's view after being in possession.
 3. It was in the sampler's possession and then was locked up to prevent tampering.
 4. It is in a designated secure area.
- o Samples are accompanied by a Chain-of-Custody (COC) Form or Record (Figure A.1-2). When transferring samples, the individuals relinquishing and receiving them should sign, date, and note the time on the form. This form documents sample custody transfer from the sampler, often through another person, to the analyst, who is in a mobile or contract laboratory.
- o Samples are packaged properly for shipment and dispatched to the appropriate laboratory for analysis, with a separate COC record accompanying each shipment. The method of shipment, courier name(s), and other pertinent information such as the laboratory name should be entered in the "Remarks" section of the COC record.
- o All shipments are accompanied by a COC record identifying their contents. The original form accompanies the shipment; the copies are retained

by the sampler and returned to the sampling coordinator.

- o The Chain-of-Custody form must indicate the preservative used for the sample.
- o Freight bills, postal service receipts, and bills of lading should be retained as part of the permanent documentation for the COC records.

8. Photographic Logs

For all photographs taken, a photographic log is kept; the log records date, time, subject, frame and roll number, and photographer. For "instant photos," the date, time, subject, and photographer are recorded directly on the developed picture. The serial numbers of the camera and lens are recorded in the project notebook. The photographer should review the photographs or slides when they return from development and compare them to the log to ensure that the log and photographs match. It can be particularly useful to photograph the labeled sample jars before packing them into shipping containers. A clear photograph of the sample jar--showing the label, any evidence tape sealing the jar, and the color and amount of sample--can be most useful in reconciling any later discrepancies.

9. Records and Inspection

- o All drilling and sampling activities should be continuously inspected by qualified, experienced personnel. Continuous inspection is essential to ensure that the intent of the drilling program is being followed and to provide knowledgeable direction to the field crews when conditions dictate variance from the original plan.

- o Inspection personnel should prepare daily reports that include the following:
 - o Field logbooks
 - o Boring logs
 - o Sample documentation.
- o Reporting is essential to adequately document unusual site conditions, drilling and sampling quantities, and the personnel onsite for project control and to thoroughly document technical methods and results.

10. Geological Logging

- o Geological logging, as previously defined, includes keeping a detailed record of drilling (or excavating) and a geological description of materials on a prepared form. Geological logs are used for all types of drilling and exploratory excavations and include descriptions of both soil and rock. General guidance for logging soils and rock is provided below.

Methods - Soils

- o When drilling in soils or unconsolidated deposits, keep the log on a sample boring log form. The following basic information should be entered on the heading of each log sheet:
 - o Project name and number.
 - o Boring or well number.
 - o Location (approximate in relation to an identifiable landmark; will be surveyed).
 - o Elevation (approximate at the time; will be surveyed).
 - o Name of drilling contractor.

- o Drilling method and equipment.
- o Water level.
- o Start and finish (time and date).
- o Name of logger.
- o In addition to the items listed above, all pertinent observations about drilling rate, equipment operation, or unusual conditions should be noted. Such information might include the following:
 - o Size of casing used and method of installation.
 - o Rig reactions such as chatter, rod drops, and bouncing.
 - o Drilling rate changes.
 - o Depth and percentage of fluid losses.
 - o Changes in fluid color or consistency.
 - o Material changes.
 - o Zones of caving or heaving.

Methods - Rock

- o When drilling and coring in rock, keep the log on a sample boring log form. Basic information should be entered on the heading, as described in the soil section. The following technical information is entered in the log:
 - o Depth
 - o Core length
 - o Coring rate in minutes per foot
 - o Fluid gain or loss
 - o Core loss
 - o Percentage of recovery
 - o Core breakage due to discontinuities
 - o Total core breakage

- o Number of breaks per foot
- o Rock classification and lithology.
- o In addition to the items listed above, pertinent observations concerning drilling rate, equipment operation, or unusual conditions should be noted. Such information might include the following:
 - o Casing type and diameter
 - o Type of drilling fluid
 - o Rig reactions
 - o Depth and percentage of fluid losses
 - o Material changes
 - o Zones of caving.

11. Variances

A variance is a deviation from project requirements. All variances from procedural and planning/design documents and other project requirements shall be documented in the site logbook. The Contracting Officer's Representative (COR) shall approve field changes that have a major impact on cost, schedule, and/or technical performance before incorporation. Project reports shall detail all field changes and deviations.

SECTION B
Drilling and Well Installation

SOP NUMBER: B.1

DATE: April 1989

TITLE: Drilling Procedures

SCOPE: This procedure describes drilling requirements for monitoring wells. A Dames & Moore geologist or hydrogeologist shall monitor all well construction activities.

RELATED SOPS: This SOP complements SOP B.2, Well Installation Requirements, which describes standard practices for installing screen, casing, and other parts necessary to complete a well in usable form. For USATHAMA activities, drilling techniques shall conform to requirements described in USATHAMA (1987).

SOPs C.6, C.6, and C.7 describe the sampling techniques which may be implemented as part of the drilling procedure.

OBJECTIVES: The activities described in this SOP are intended to assure that:

- o Wells provide representative samples of groundwater for analysis.
- o Wells permit measurement of representative water levels.
- o Drilling activities do not cause cross-contamination between wells or between hydrogeological units in the same well.
- o Drilling activities are fully documented.

EQUIPMENT:

- o Drilling equipment and supplies. (Because of the wide variations possible, a list of equipment and supplies is generally developed by the drilling contractor on the basis of specifications for individual wells or groups of wells.)
- o Field notebook.
- o Boring log forms.
- o Copies of relevant work plans (including USATHAMA Geotechnical Requirements (USATHAMA, 1987)).
- o Hand lens.

- o Munsell or Geological Society of America soil color chart.
- o Camera and film.

**STEAM
CLEANING:**

Before starting the first well at a site, steam clean the drilling rig, drilling tools and pipe, support vehicles, water tanks (inside and outside), well casing, and well screen. Cover steam-cleaned tools, casing, and screen with new clean plastic sheeting before moving to the first well location.

After drilling each well, steam clean all tools, casing, and screen needed for the next well before moving to the next well location. Cover steam-cleaned tools, casing, and screen with new clean plastic sheeting before moving to the next well location.

Steam clean the drilling rig, drilling tools and pipe, support vehicles, and water tanks (inside and outside) before leaving the site.

**QUALITY
CONTROL
OBJECTIVES:**

Objectives in terms of quality control are as follows:

- o Prevent spread of contamination, in particular contamination of aquifers or wells that might falsely indicate the extent of contamination.
- o Document drilling activities accurately and completely.
- o Promote safe working conditions.

**RECORD
KEEPING:**

Record keeping shall be in accord with SOP A.1, Field Record-keeping. Note that the original drilling log must be submitted to USATHAMA within three days of completion of a well.

Work assignments, chronology (such as periods of drilling and down time), difficulties encountered, decontamination activities, sampling activities, and the like shall be recorded in the field notebook assigned to every field person.

Soils and rock penetrated, drilling rate, groundwater encountered, well construction, and the like shall be recorded on drilling log forms.

DRILLING

PROCEDURES:

Drilling within the overburden soil zone will be by hollow-stem auger (HSA) (10½-inch O.D.; 6 5/8-inch I.D.). To permit development of a detailed lithologic log (see Figure A.1-4), split-spoon sampling will be conducted at 5-foot intervals or when a major stratigraphic change is noted during the drilling of all wells.

Drilling within bedrock will involve collection of NX rock core followed by overreaming to a nominal 6½-inch borehole. Hollow-stem augers will be used to drill through the overburden as described above and left in place a temporary casing during the coring. Overreaming will be performed by either hydraulic rotary using USATHAMA-approved water or air rotary techniques. The only drilling fluid additive to be used is bentonite, if pre-approved by USATHAMA. If air rotary techniques are used, the drilling air supply will be filtered by a three-state air filter.

REFERENCES

USATHAMA, 1987. Geotechnical Requirements for Drilling, Monitor Wells, Data Acquisition, and Reports, Department of the Army, U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, MD, 65 p.

SOP NUMBER: B.2

DATE: September 1989

TITLE: Well Installation Requirements

SCOPE: This operating procedure describes installation requirements for monitoring wells.

A Dames & Moore geologist or hydrogeologist shall monitor all well construction activities.

OBJECTIVES: The activities covered by this procedure apply to construction of monitor wells that will:

- o Provide representative samples of groundwater for analysis.
- o Permit collection of representative water level data.
- o Effectively isolate the separate hydrogeologic strata penetrated during drilling.

EQUIPMENT:

- o Drilling rig, drilling tools, and support truck with water tanks.
- o Steam cleaner.
- o Grout plant and tremie pipe.
- o Portland cement, Types II or V.
- o Well casing and screen, with cap and bottom plug.
- o Protective steel casing and padlock.
- o Concrete mix.
- o Reinforcing wire mesh.
- o Powdered bentonite.
- o Bentonite pellets.
- o Sand for filter pack.
- o Plastic sheeting.

Well Installation Procedures:

- o To sample groundwater from the top of the water table (i.e., when contaminants of concern float), borings should be completed approximately 8 feet below the water table and a 10-foot well screen installed to stretch from above to below the water table.
- o To sample for contaminants in the overburden below the water table, borings must be drilled 10 feet or more below the water table and a 10-foot well screen installed.
- o To sample groundwater within the bedrock, wells will be completed to a depth of 28 feet below unweathered bedrock and have 15-foot screens.

Well Installation/Construction Requirements:

- o Well screens/casing and protective casings shall be decontaminated with high-pressure steam and covered with plastic sheeting if storage is necessary.
- o The following evidence shall be recorded in monitoring well construction:
 - o Type, grade, and quality of material.
 - o Quantity of material.
 - o Method of decontamination.
 - o Dimensions of well casing and screen and depths to annular fill materials.
- o All joints on casing and well screen shall be threaded, flush joints.
- o Teflon tape is the only thread sealing material to be used in monitoring well construction.
- o Well construction materials consist of 4-inch ID schedule 40 polyvinyl chloride (PVC).

- o The filter pack shall be analyte-free, inert, well rounded, and uniform in size (quartz sand, glass beads). The filter pack should be properly sized for the aquifer matrix to reduce settleable solids and must extend 5 feet above the top of the screen.
- o Annular seals shall be a minimum of 5 feet of bentonite pellets or a maximum of 5 feet of batter-like bentonite slurry above the filter pack, with cement/bentonite grout in a ratio of 20 parts Portland cement to one part bentonite from the top of the bentonite seal to ground surface. Granular/flake bentonite should be used on shallow or unsaturated conditions, and pelletized bentonite should be used on deep or saturated conditions. All bentonite seals shall be hydrated following manufacturers' instructions.
- o A steam-cleaned steel protective casing with lockable cap shall be placed over the well casing and cemented into the ground. The protective casing is to extend no more than 0.2 foot above the well casing. The casing and cap are to be painted orange with a brush and be dry prior to initial sampling.
- o A gravel apron will have a minimum radius of 4 feet surrounding the well and will be approximately 6 inches thick, composed of coarse gravel, and be placed prior to development.
- o The well designation will be painted on the protective casing with white paint and a brush and will be dry prior to initial sampling.
- o Protective posts, four per well, shall be installed radially, 4 feet from each well, with a minimum of 3 feet above

ground surface, and painted orange with a brush. Installation and painting will be completed prior to initial sampling.

- o As-built drawings shall be completed for each well and submitted to USATHAMA within 3 working days following completion of each well installation.
- o The location of the well shall be measured by a licensed surveyor. The elevation of the top of well casing and the top of protective casing will be measured accurately to ±0.01 foot.
- o Technical information shall be recorded on the Well Construction Diagram.
- o Flush-mounted wells or wells subject to flooding shall not be vented. To this end, a watertight cap must be provided to prevent the entry of surface water. However, this situation is to be avoided and will be handled on a case-by-case basis with the COR.

SECTION C

Sampling Methodologies and Other Field Procedures

SOP NUMBER: C.1

DATE: September 1989

TITLE: Groundwater Sampling With Bailer

SCOPE: This operating procedure describes steps involved in well purging and preparation for taking groundwater samples using a bailer and its accessory equipment. Manufacturer's specifications and recommendations for the bailer should be followed or referred to as necessary.

OBJECTIVES: The activities covered by this procedure:

- o Obtain groundwater samples for laboratory and field analysis.
- o Ensure that the groundwater samples taken will be representative of actual groundwater quality.
- o Ensure quality control and consistency in taking samples.
- o Serve as a means to allow traceability of error(s) in sampling and data recording.

EQUIPMENT:

- o Bailer constructed of PVC, teflon, or stainless-steel pipe.
- o A reel to raise and lower bailer as needed depending on well depth.
- o A line (wire) to lower bailer; made of teflon, polypropylene, nylon, or stainless steel.
- o A new plastic sheet to cover the ground and on which to place bailer, pump, line, reel, and water level tape.
- o pH meter, conductivity meter, and thermometer.
- o A field log, groundwater sampling record form, and calculator.
- o Sample containers with labels.

- o A water level measuring tape.
- o Photoionization detector such as an HNu meter.

**PRELIMINARY
TO OPERATION:**

1. The bailer, reel, line, water level measuring tape, thermometer, and pH and conductivity meters should be examined for cleanliness and checked for defects and any possible need for repair.
2. Batteries should be checked in the pH meter (SOP D.1), conductivity meter (SOP D.2), and calculator.
3. The bailer, reel, line, pump, tubing, and water level measuring tape should be placed on the ground atop a new plastic sheet.
4. The preferred sampling method for VOA analytes is the use of a bottom filling bailer or other equipment that will not agitate or potentially volatilize the analytes.
5. The well should be "sniffed" with the photoionization detector to establish that the well is safe to sample.
6. The construction materials of the sampling equipment shall be compatible with known and suspected contaminants.

**OPERATING
PROCEDURE:**

1. Collect samples upon completion of purging if the recharge is sufficient. If a well goes dry during purging but recovers quickly, allow it to recover to its original level and then evaluate a second time prior to sampling. If recovery is very slow, collect samples as soon as sufficient volume is available.
2. Record the well number, time, and date and all pertinent information and data on the groundwater sampling record (Figure A.1-5).
3. Purge well as described in SOP C.16. Allow water to recover to approximately its original level.

4. Remove sample bails with a fresh bailer and line. Triple rinse all sample bottles and caps with sample water, filtered or unfiltered as appropriate for the container/analyte. (Note that this rinsing procedure shall not be employed in cases where pre-preserved sample bottles are used.) Use the first bail(s) for rinsing and for measuring temperature, pH, and conductivity. Use subsequent bails for VOC analysis and pour into bottle using care to remove air bubbles. Use last bail for metals analysis. Required sample containers and preservative requirements are discussed in SOP C.7. Between removing bails, do not place bailer or line on the ground unless the ground is covered with a new or decontaminated tarp or plastic sheet.
5. Affix labels to each sample bottle, recording sample number, well number, date, and time.
6. Record information in field log, including pH, temperature, and specific conductivity, along with a description of the physical appearance of the sample (e.g.; color, clarity, suspended solids, etc).
7. Immediately place samples in a shipping container maintained at 4°C.
8. Decontaminate bailers, lines, other equipment, and reel, if used.

SOP NUMBER: C.2

TITLE: Penetration Test and Split-Barrel Sampling (Based on ASTM Method D1586)

DATE: September 1989

SCOPE: This method describes the procedure for collecting a representative disturbed soil sample by using a split-barrel sampler. This sampler has been used to develop an empirical relationship between driving resistance and the relative density of soil. The procedure for determining and interpreting penetration resistance or relative density is collectively referred as the Standard Penetration Test (SPT).

OBJECTIVES: The method covered by this procedure:

- o Provides a soil sample for identification/classification purposes.
- o Provides an adequate quantity of disturbed soil sample for laboratory testing for its physical characteristics.
- o Allows engineering correlations to be made concerning the behavior of subsurface materials.

EQUIPMENT:

- o Drilling Equipment - Any drilling equipment should be acceptable that provides a reasonably clean borehole before insertion of the split-barrel sampler, to ensure that the penetration test is performed on undisturbed soil, and that permits the driving of the sampler to obtain the sample and blow-count record in accordance with the procedure described under "Operating Procedure."
- o Split-Barrel Sampler - A split-barrel sampler is so named because the main section of the sampler consists of a section of pipe that splits into two pieces along the axis of the pipe. A driving shoe and waste barrel screwed to the ends hold the split section

together during driving. Aids for sample retention may also be incorporated into the split-barrel sampler. These would be catchers, spring or gravity traps (in the lower end), and check valves (in the top end). The standard sampler has an outside diameter of 2 inches (50.8 mm) and an inside diameter of 1-3/8 inches (35 mm). The Dames & Moore Type U Sampler (3.25 inches outside diameter and 2.42 inches inside diameter) can also be used to provide relatively undisturbed samples for laboratory testing of soil engineering properties. Other larger diameter samples (3 to 6 inches in diameter) are helpful in sampling gravel deposits and retrieving samples of sufficient volume to perform compaction tests. If a larger diameter sampler is used, however, the size should be conspicuously noted on all penetration records.

- o Drive-Weight Assembly - This consists of a rope-cathead or an automatic hammer drop system that drives the sampler into the soil. The mechanism allows a 140-pound weight to free fall 30 inches onto a driving head. Larger weights or drops may be used for larger diameter samplers. Special precaution should be taken to ensure that the energy of the falling weight is not reduced by friction between the drive weight and the hammer guides used to permit the free fall.
- o Sampling Rods - Flush joint steel drill rods should be used to connect the split-barrel sampler to the drive-weight assembly. To avoid "whips" under the blows of the hammer, the drill rod should have a stiffness equal to or greater than the A-rod. An "A" rod is a hollow drill rod having an outside diameter of 1-6/8 inches (41.2 mm) and an inside diameter of 1-1/8 inches (28.5 mm), through which the rotary motion of drilling is

transferred from the drilling motor to the cutting bit. A stiffer drill rod is suggested for sampling in holes deeper than 50 feet (15 m).

- o Accessory Equipment - When drilling in sand or in soft clay or other material that will not allow a hole to stay open, casing or drilling mud should be used. Accessories such as labels, sample containers, and data sheets should also be provided (Figure C.2-1).

PRELIMINARY TO OPERATION:

1. To prepare the borehole, it should be cleaned out to the sampling elevation using whatever equipment will ensure that the material to be sampled is not disturbed by the operation. When drilling in saturated sands and silts, the bit should be withdrawn slowly to prevent loosening of the soil around the hole.
2. Several drilling methods produce unacceptable borings. The following should not be used:
 - a. Drilling with a bottom-discharge bit (side-discharge bits would be permissible).
 - b. Using the process of jetting through an open-tube sampler and then sampling when the desired depth is reached.
 - c. Using continuous flight solid augers to advance the boring below the water table or below the upper confining bed of a confined noncohesive stratum that is under artesian pressure.
 - d. Driving casing below the sampling elevation before collecting a sample.
 - e. Continuously sampling using the SPT method and not advancing the boring between samples with the drill bit using acceptable drilling procedures to ensure access to undisturbed soil.

FIGURE C.2-1

SOIL SAMPLE CONTAINER LABEL

0606		
Dames & Moore		
JOB NO _____		
BORING	DEPTH	SAMPLE NO _____
DATE	BY	
OWNER _____		
LOCATION _____		
SOIL TYPE _____		

0606		
Dames & Moore		
JOB NO _____		
BORING	DEPTH	SAMPLE NO _____
DATE	BY	
OWNER _____		
LOCATION _____		
SOIL TYPE _____		

**OPERATING
PROCEDURE:**

1. Ground control for sample location shall be within ±2 feet of the identified location or consistent with data quality objectives.
2. Typically, samples are taken at every change in stratum and at intervals not greater than 5 feet (unless otherwise stipulated by the field engineer or geologist).
3. After the boring has been advanced to the desired sampling depth and extracted drill cuttings have been suitably removed, a standard penetration test is performed as follows:
 - a. A split-barrel sampler (outside diameter 2 inches, inside diameter 1-3/8 inches) attached to drill rods ("A" rod or larger to prevent rod whip during driving) is lowered to the bottom of the cleaned-out borehole.
 - b. Three 6-inch increments are marked on the dull rods above a convenient fixed datum.
 - c. The sampler is driven by a 140-pound hammer free falling a distance of 30 inches onto a collar or drive head on the drill rods. The sampler is driven a total of 18 inches into the undisturbed soil, and the number of blows required to advance each 6-inch increment is recorded.
 - 1) The "blow count" for the standard penetration test is the total number of blows required to drive the sampler the last foot (i.e., the sum of the blows required to drive the sampler to the second and third 6-inch increments).
 - 2) If an erratic blow count is encountered in the last 6-inch segment, it may be due to

a filled sampler, obstruction to driving, or change in strata. The reason for change should be noted on the boring log.

- 3) If the change can be explained by a factor other than a change in strata, twice the count for the second 6-inch segment may be used as an approximate SPT "blow count."
- 4) Correlation of SPT blow counts with soil consistency or compactness is determined using the table below:

Clay and Silt

Blows/Foot	Consistency
0-1	Very Soft
2-4	Soft
4-8	Medium Stiff
8-16	Stiff
16-32	Very Stiff
32	Hard

Sand

Blows/Foot	Compactness
0-4	Very Loose
4-10	Loose
10-30	Medium Dense
30-50	Dense
50	Very Dense

- d. The standard penetration test should be terminated if one of the following occurs:
- 1) A total of 50 blows have been applied during any one of the three 6-inch increments.
 - 2) A total of 100 blows have been applied.

- 3) There is no observed advance of the sampler during the application of 10 successive blows of the hammer.
 - e. After total penetration of the sampler has been achieved, the sampler is retrieved to the surface and opened.
 - f. Representative samples are carefully described according to percent recovery, soil composition, structure, consistency, color, and condition. If photographs of cores are required, include a Kodak 18 percent Gray Card in each photograph to allow standardization of color prints.
 - g. Representative samples are placed into moisture-proof containers, making sure that the sample is not distorted upon insertion. Samples for chemical analysis should have that portion of the soil that is in contact with the sampler "peeled" (i.e., removed and discarded) prior to bottling. If there is a soil change within the sampler, a representative sample of each stratum is placed in jars and the depth at which the change took place is noted.
 - h. Soil sample container labels, shown in Figure C.6-1, are completed and affixed to the containers.
 - i. All samples are protected against extreme temperature changes. Freeze indicators should be packed with each sample shipment during cold weather.
4. All samples not submitted for either physical testing or chemical analyses will be neatly stored onsite at USATHAMA-designated locations; ultimate disposition will be arranged between USATHAMA and the host installation.

SOP NUMBER: C.3

DATE: September 1989

TITLE: Soil Sampling Using a Hand Auger or a Stainless-Steel Trowel

SCOPE: This practice describes the equipment and procedures to secure soil samples with a hand auger or stainless-steel trowel.

OBJECTIVE(S): The activity covered by this practice is used to obtain surface and near-surface soil samples collected from areas of known or suspected chemical releases or waste disposal.

EQUIPMENT:

- o Hand augers, with stainless-steel scoops
- o Stainless-steel buckets
- o Stainless-steel hand trowel
- o Airtight collector jars to store collected samples
- o An HNu or other organic vapor monitoring instrument.

PRELIMINARY TO OPERATION:

1. The trowel or hand auger should be decontaminated, examined for cleanliness, and checked for defects or any need of repair.
2. A description of the sampling station. The immediate area from which the sample is being taken and other pertinent sample information shall be recorded in the field logbook.
3. The sample collection point shall be within 2 feet of the identified location, unless the data quality objectives require more accuracy and precision.
4. Inspect sample containers for cleanliness.

OPERATING PROCEDURE:

1. Scoop up samples with trowel and put into collector jar.
2. If using hand auger, scoop sample from auger into collector jar using trowel.

3. Fill jar to as full as possible and seal tightly to eliminate loss of volatiles.
4. Wipe sealing surface and all sample containers dry and label. Place containers on ice for temporary storage.
5. Record field observations and sample details in the field log using the Soil Sampling Record (Figure A.1-9).
6. Identify all soil sample locations on the ground. Use identification materials and markings that will last until the end of the project.
7. Collect and contain soil samples for volatile organic analytes as undisturbed as possible.
8. Care must be taken to prevent cross-contamination and misidentification of samples, particularly during depth-profile sampling.

SOP NUMBER: C.4

DATE: September 1989

TITLE: Equipment Blank Sampling

SCOPE: The activities covered by this procedure:

- o Ensure quality control in field sampling operations.
- o Serve as a means to allow traceability of possible causes of sampling error or analytical techniques.
- o Provide documentation of contamination control procedures.

EQUIPMENT:

- o Sampling device for matrix blank to be obtained (e.g., bailer for groundwater, Kemmerer bottle for surface water, hand auger or split spoon for soil).
- o Sample containers with labels.
- o Field tracking forms (sampling logs and chain-of-custody log).
- o Distilled water.

OPERATING PROCEDURE:

1. Obtain appropriate sample containers (see SOP D.2). Blank analyses must include all parameters of interest that were sampled that day.
2. Fill the cleaned equipment with organic-free distilled water.
3. Fill each sample container with water from the equipment. For open-ended equipment, fill sample containers by pouring organic-free distilled water through the equipment into the sample containers or, if necessary, by collecting the rinse water in a clean, unused container. Fill volatile containers first, proceeding to the nonvolatiles.

4. Filtration of the blank should correspond to sample collection criteria (i.e., if groundwater metals samples are filtered, bailer blanks should also be filtered).

SOP NUMBER: C.5

DATE: September 1989

TITLE: Decontamination Procedures

SCOPE: The acceptable decontamination procedures for all equipment used in the field.

OBJECTIVES: The activities covered by this procedure:

- o Ensure quality control in decontamination of all sampling and nonsampling field equipment.
- o Serve as a means to allow traceability of errors in procedures.

EQUIPMENT: o Distilled and USATHAMA-approved water (i.e., untreated, unfiltered water from an onsite well that is free of site-related contaminants based on review of analytical sampling)

- o Sprayer
- o 5-gallon pail
- o Nylon scrub brush and long-handled bottle brush
- o Paper towels
- o Trash receptacle
- o Plastic sheeting (polyethylene).

PROCEDURES: Nonsampling Equipment
All drilling equipment, well screen/casing, backhoe, dredges, augers, and other nonsampling equipment shall be decontaminated with high-pressure steam using USATHAMA-approved water and, if applicable, covered with plastic sheeting (protected from the elements).
Sampling Equipment

1. Wash and scrub with USATHAMA-approved water.
2. Rinse with distilled water.

3. Air dry, if time allows.
4. Protect from fugitive dust or vapors by wrapping with plastic sheeting.

SOP NUMBER: C.6

DATE: September 1989

TITLE: Groundwater Well Development and Purging

SCOPE: This operating procedure describes the quality control requirements for groundwater well development and pre-sample purging.

OBJECTIVE: To maintain quality control during the development and purging of groundwater wells.

EQUIPMENT:

- o Bailer constructed of PVC or stainless-steel pipe.
- o A reel to raise and lower bailer and pump as needed depending on well depth.
- o A line (wire) to lower bailer and pump; made of teflon, polypropylene, nylon, or stainless steel.
- o A new plastic sheet on which to place bailer, pump, line, reel, and water level tape.
- o pH meter, conductivity meter, and thermometer.
- o A field log, groundwater well purging/development record (Figure A.1-6), and calculator.
- o One pint jar if developing or sample containers with labels if purging.
- o A water level measuring tape.
- o Photoionization detector such as an HNu meter.
- o Stainless-steel electric submersible pump.
- o Centrifugal pump for shallow purging.
- o Polyethylene or teflon flexible tubing.
- o Flow meter or volumetric flow measuring device.
- o 4500-watt generator.
- o Stainless-steel hose clamps.

- o Electrical pump wire.

**PRELIMINARY
TO OPERATION:**

1. The bailer, pump, reel, line, water level measuring tape, thermometer, and pH, and conductivity meters should be examined for cleanliness, and checked for defects and any possible need for repair.
2. Batteries should be checked in the pH meter (SOP D.1), conductivity meter (SOP D.2), and calculator.
3. A new plastic sheet should be spread on the ground for placement of the bailer, reel, line, pump, tubing, and water level measuring tape.
4. The well should be "sniffed" with the photoionization detector to establish that it is safe to operate near the well.
5. All equipment is to be decontaminated according to SOP C.5.

**GENERAL
REQUIREMENTS:**

Monitoring Well Development

1. At least 48 hours, but not more than 7 days, will be allowed to elapse after grout and internal mortar collar placement before beginning development.
2. Development will normally be conducted by pumping or bailing the well and allowing the water level to recover. Surging, jetting, air development, and similar aggressive techniques only if pumping and recovery are ineffective and only if authorized by the Dames & Moore field manager after consulting the COR. Justification for the use of such development methods will be recorded in the field notes.
3. Development will continue (except as provided in the following paragraph) until the following conditions are met: (1) at least five volumes of water in the casing,

screen, and saturated annulus have been removed, along with five times the volume of any fluids lost during drilling or well installation, (2) the discharged water contains no visible particles or turbidity, and (3) the sediment thickness remaining in the well is less than 1 percent of the screen length.

4. If five volumes cannot be removed within 48 hours, or if particles or turbidity persist after 2 working days of development, contact the COR for guidance.
5. A 1-pint sample of water will be obtained from each well at the end of development and will be given to a USATHAMA-designated individual for disposition.
6. Well development procedures, including at least four sets of measurements of pH, temperature, and specific conductance--at the start, twice during, and at the end of development--will be documented in the Well Purging/Development Record (Figure A.1-6), which will be submitted to the COR within 3 working days after development.

Monitoring Well Purging

1. Purging procedures have a great influence on the reliability of groundwater samples, and inconsistent purging can be a large source of variability among groundwater analyses. Therefore, purging procedures will as much as possible be standardized, as described below. Once a specific purging procedure has been used and documented on a well, the same procedure will as much as possible be used in subsequent purging.
2. All wells will be purged before sampling. At least 14 days will be allowed to elapse between development and presample purging. The purging procedure will depend on whether the well's water level recovers rapidly or slowly from purging. The recharge status of

newly constructed wells will be determined after development.

3. A minimum of five volumes will be purged from rapid-recharge wells. A volume is defined as the volume of water within the screen, casing, and saturated annulus. Pumping or bailing will take place from just below the water level in the well. The pump will be lowered during purging if necessary to keep its intake just below the water surface.
4. Purging of slow-recharge wells is based on the relative recharge rate of the well. If the well is pumped or bailed dry during purging and requires more than 4 hours to recover, remove 2 volumes of water, and then sample. If the well recovery is less than 4 hours, consider it a rapid-recharge well, and conduct purging as described above in (3).
5. Temperature, pH, and specific conductance will be monitored during purging. Stabilization of these parameters during purging increases confidence that samples are representative of groundwater, though it does not guarantee stabilization of concentrations of contaminants, since these parameters have little relation to the presence of many of the common contaminants in concentrations often of significance.
In rapid-recharge wells, at least four samples will be taken for this purpose at roughly equal intervals during purging. In slow-recharge wells, a sample will be taken near the beginning and near the end of each evacuation cycle.
6. Upgradient wells, background wells, and other wells that available information suggests are relatively uncontaminated will be purged and sampled first, whenever feasible. This practice is intended to guard against contamination from more contaminated wells.

7. Procedures and quantities associated with purging each well will be documented on the Well Purging/Development Record (Figure A.1-6).

OPERATING PROCEDURES:

1. Record the well number, time, and date and all pertinent information and data on the Well Purging/Development Record (Figure A.1-6).
2. Measure the depth to groundwater in the well and to the bottom of well/top of sediment to the nearest 0.01 foot with a weighted tape.
3. Calculate the volume of water in the well using the equation:

$$V = 7.48 (r^2 h + 0.3 (R^2 - r^2)H)$$

where V = Volume of water in well, in gallons

7.48 = Conversion factor, cubic feet to gallons

r = radius of well, in feet

R = Radius of borehole, in feet

h = distance from well bottom to water surface in well, in feet

H = distance from bottom of sand pack to water level, or from bottom of sand pack to top of sand pack, whichever is less, in feet

0.3 = porosity of sand pack.

This calculation of well volume includes water in the well casing and in the borehole annulus and assumes a porosity of 30 percent in the annulus.

4. For well development, include fluid volumes lost in drilling and well construction when calculating volume removal objectives.

5. Inspect the submersible pump and wiring to make sure that they have been properly decontaminated.
6. Connect new teflon or polyethylene flexible pipe to stainless-steel barbed fitting on top of the submersible pump. Secure with a stainless-steel hose clamp.
7. Attach safety line (consisting of either teflon, polypropylene, nylon, or stainless steel) to the submersible pump and connect pump wiring to the submersible pump.
8. Slowly lower the submersible pump into the well, taking care not to allow jamming. Lower to the desired level (preferably to well bottom) and tie to well protective casing using safety line.
9. Connect flexible piping to the sealed register flow meter. Make sure to note the initial flow meter reading.
10. Start the generator and plug wire into outlet, and immediately check flow meter to ensure proper operation. Also check flow rate in gallons/minute.
11. Monitor water level using the electric measuring tape. Continue pumping until five well volumes, as calculated in Step 4, have been removed or until the well goes dry.
12. Slowly pull the pump from the well using the safety line.

SOP NUMBER: C.7

DATE: September 1989

TITLE: Sample Container Volumes, Preservation, and Holding Times

SCOPE: This operating procedure describes methods for selecting the appropriate containers for environmental samples.

OBJECTIVES: To ensure that sample volumes and preservations are sufficient for analytical services.

EQUIPMENT:

- o Sample containers
- o Shipping containers
- o Sample labels.

OPERATING PROCEDURE:

1. Refer to Table C.7-1 for minimum sample volume, container type, preservation methods, and holding times for particular parameter analyses.
2. Select the appropriate jar(s) from those provided by the laboratory and verify that the laboratory has provided the correct number of jars for the project per sample plan requirements.
3. Report any discrepancies to the Project Manager and the Quality Assurance Officer or his representative immediately.
4. Apply sample labels to containers and label project name.
5. Proceed with sampling.

TABLE C.7-1

**Information on Sample Container, Preservation,
and Holding Time Requirements**

Analyte(a)	Container Requirements(b)	Preservation(c)	Maximum Holding Times(d)
WATER SAMPLES			
<u>Explosives</u>	1-Liter G(A)	None	7 days until extraction; 40 days after extraction
<u>Anions</u>			
Nitrate/nitrite and Phosphate	1-Liter P	H ₂ SO ₄ to pH<2	28 days
Sulfate	1-Liter P	None	28 days
TAL Metals			
Mercury	1-Liter P	HNO ₃ to pH<2	28 days
Hexavalent Chromium	1-Liter P	HNO ₃ to pH<2	24 hours
Other metals	1-Liter P	HNO ₃ to pH<2	6 months
TCL VOCs in water			
	60-ml. G vials with Teflon septum caps, 4 per sample	HCl to pH2	10 days
TCL BNAs	(2) 1-Liter G(A)	None	7 days until extraction; 40 days after extraction
TCL PCBs/Pesticides	(2) 1-Liter G(A)	None	7 days until extraction; 40 days after extraction

TABLE C.7-1 (cont'd)

Analyte(a)	Container Requirements(b)	Preservation(c)	Maximum Holding Times(d)
TPHCs	(2) 1-Liter G(A)	H ₂ SO ₄ to pH<2	28 days
SOIL SAMPLES			
Explosives	(2) 500-ml. wide-mouth G(A) with Teflon-lined cap	None	7 days until extraction; 40 days after extraction
Anions Nitrate/nitrite & Phosphate	(2) 500-ml. wide-mouth G(A) with Teflon-lined cap	None	28 days
Sulfate	(2) 500-ml. wide-mouth G(A) with Teflon-lined cap	None	28 days
TAL Metals Mercury	(2) 500-ml. wide-mouth G(A) with Teflon-lined cap	None	28 days
Hexavalent Chromium	(2) 500-ml. wide-mouth G(A) with Teflon-lined cap	None	24 hours
Other Metals	(2) 500-ml. wide-mouth G(A) with Teflon-lined cap	None	6 months
TCL VOCs in soil	(2) 40-ml. G(A) wide mouth with Teflon-lined cap	None	10 days

TABLE C.7-1 (cont'd)

<u>Analyte(a)</u>	<u>Container Requirements(b)</u>	<u>Preservation(c)</u>	<u>Maximum Holding Times(d)</u>
<u>TCL BNAs</u>	(2) 500-ml. wide-mouth G(A) with Teflon-lined cap	None	7 days until extraction; 40 days after extraction
<u>TCL PCBs/Pesticides</u>	(2) 500-ml. wide-mouth G(A) with Teflon-lined cap	None	7 days until extraction; 40 days after extraction
<u>TPHCS</u>	(2) 500-ml. wide-mouth G(A) with Teflon-lined cap	None	28 days

(a) BNAs = Base-neutral and acid extractable organics

PCB = Polychlorinated biphenyl

TAL = Target Analyte List

TCL = Target Compound List

VOCs = Volatile organic compounds

TPHCS= Total Petroleum Hydrocarbons

(b) P = Plastic

G = Glass

G(A) = Amber glass

(c) In addition to cooling to 4 C, which is applicable to all samples.

(d) From date of sampling except for TCL VOCs which are from date of laboratory receipt.

SOP NUMBER: C.8

DATE: September 1989

TITLE: Sample Shipping

SCOPE: This operating procedure describes methods for properly shipping environmental samples collected at site investigations.

OBJECTIVES: The activities covered by this procedure:

- o Ensure quality control in the shipping of environmental samples.
- o Allow uniformity of operation between different field personnel.
- o Serve as a means to allow traceability of samples in shipment.
- o Set forth procedures assuring legal chain of custody for environmental samples collected at site investigations.

EQUIPMENT:

- o Chain-of-custody forms.
- o Shipping containers.
- o Shipping tape and packing materials.
- o Blue icepacks (frozen no less than 12 hours, no more than 18 hours) or ice.
- o Labels.

PROCEDURE:

1. Place each sample in the shipping cooler as collected. Blue icepacks or approximately 5 pounds of ice, double bagged, should be in the cooler to maintain proper temperature.
2. When the cooler is filled, verify that each sample in the cooler is listed on the sample tracking form.

3. Number each cooler. Note on the sample tracking form the cooler number in which each sample is shipped.
4. Complete a chain-of-custody form (SOP A.1, Figure A.1-2) for each shipping container of samples.
5. At the end of each day, check all coolers prior to shipment to the laboratory. Verify cooler contents vs. chain of custody, check packing to minimize potential breakage, and add/replace ice or blue icepacks as needed to maintain proper temperature during shipment. Tape cooler shut, and apply custody seal. Do not relinquish custody of the samples to the shipper until the chain-of-custody form is signed and a copy is retained for records. The original chain-of-custody form and the original field tracking form are to be submitted to the laboratory sealed in plastic bags that are placed in the cooler prior to shipment.

NOTE: Although samples containing high and medium concentration levels of hazardous constituents are not anticipated, any that might be collected will require special packaging if they are to be shipped to the laboratory by commercial air. Under these circumstances, the protocol identified in the "Users Guide to the CLP" will be followed.

REFERENCE:

EPA OERR, October 1984. Users Guide to the Certified Laboratory Program, USEPA Office of Emergency and Remedial Response.

SOP NUMBER: C.9

DATE: December 1989

TITLE: Groundwater Level Measurement by Tape

SCOPE: This operating procedure describes methods for taking and recording manual water level measurements in wells by means of steel, fiberglass, electric, and/or similar devices. Water levels may be observed with the steel or fiberglass tapes with an attached "popper" weight, which makes a popping sound when it strikes the water surface. An electric tape produces a meter, sound, or light response when the electrode contacts the water surface.

OBJECTIVES: This standard procedure is intended to:

- o Assure that water levels measured at different times and by different personnel are comparable, uniform, and reliable.
- o Allow traceability of error in water level measurement and correction of improper procedures.
- o Assure that data obtained in the field are complete and of satisfactory precision and accuracy.

EQUIPMENT:

- o Steel, fiberglass, or electric tape (Steel or fiberglass tapes should be graduated in feet to hundredths. Electric tapes, such as the Fisher "M-Scope," are often graduated only at 5-foot intervals.)
- o Pocket steel tape or folding ruler (graduated in feet to hundredths)
- o Paint and marking pen for permanently marking well with its number and marking the measuring point
- o Preprinted water level measurement forms (Figures C.9-1 and C.9-2)

FIGURE C.9-1

GROUNDWATER LEVELS – SINGLE WELL

Job No. _____

Well No. _____

Job Name _____

Site _____

Area _____

Measuring Point Description _____

Stickup _____ ft measured up (+) / down (-) from _____

MP elevation _____ **Datum = MSL or** _____

Remarks _____

Measurement Method:

A = Airline
C = Chalk and tape
E = Electric tape
T = Tape with popper
X = Other (describe in remarks)

Well Status:

D = Dry
F = Flowing
P = Pumping
RP = Recently pumped

NP = Nearby well pumping
NRP = Nearby well recently pumped
X = Obstructed

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FIGURE C.9-2

GROUNDWATER LEVELS – MULTIPLE WELLS

Project Name _____

Job No. _____

Project Location _____

Job Name _____

Remarks _____

MP = Measuring point (usually top of casing). Describe in remarks.

Measurement Method:

A = Airline
C = Chalk and tape
E = Electric tape
T = Tape with popper
X = Other (describe in remarks)

Well Status:

D = Dry
F = Flowing
P = Pumping
RP = Recently pumped

**NP = Nearby well pumping
NRP = Nearby well recently pumped
X = Obstructed**

- o Field notebook
- o Batteries for electric tape
- o Clean rags or Kimwipes
- o Distilled or deionized water, organic-free if well is to be sampled for organics

Tape calibration: A standard steel tape with calibration traceable to the National Bureau of Standards is maintained in the Dames & Moore soils laboratory. It is not used for field measurements but only for calibrating field tapes.

New field tapes will be calibrated against the standard tape before use by stretching both along a flat, level surface and applying to each a tension approximately equal to the weight of the tape. For each 10 feet of distance along the standard tape, the corresponding reading of the field tape will be recorded and filed by the laboratory manager.

The tape number assigned by the laboratory manager will be permanently marked on the tape case or frame and on the tape itself at the 5-foot mark.

Measuring point: The measuring point is the fixed point on the well from which all water level measurements are taken. In general, it will not be at ground level but is usually a point on top of the casing. Typically, monitoring wells are constructed with an inner casing that is connected to the screen or that extends into bedrock and with an outer steel protective casing. If the inner casing is easily accessible, the measuring point should be chosen as the highest point on its rim; if necessary, use a steel file to produce a clean, sharp edge. If the inner casing is not accessible, choose the lowest point on the outer casing as the measuring point.

The measuring point must be permanently marked. Usually it will be most convenient to put a spot on the casing rim

with a permanently marker, with an arrow and the letters "MP" pointing to it. A bottle of opaque nail polish or auto touch-up enamel containing a small brush are acceptable alternatives if the marking pen proves inadequate. The measuring point should be marked before surveying, and the surveyor directed to determine the elevation of the marked point.

Experience shows that considerably more error in groundwater level measurements comes from mistaking the identity of a well or the location of the proper measuring point than from errors in the actual measurement. It is essential that the well and measuring point be clearly identified. If field technicians notice an unmarked well, they are responsible for permanently marking the well number and measuring point location. The well number may be painted on the outside of the casing or inside of the protective cap, as long as it is obvious to anyone opening the well for measurement.

**PRELIMINARY
TO OPERATION:**

1. Inspect tape to make sure that it is complete and moves freely in its case. Make sure that plopper is firmly attached and that its lower end is a convenient distance (for example 0.50 feet) below the zero mark on the tape. Record the distance on the field log.
2. Inspect electrode tip of electric tape. Test batteries, and test operation of tape in the laboratory by placing electrode in tap water and making sure that the meter or other indicator responds. Make sure that the effective position of the electrode corresponds to the zero position on the tape. If the electrode has been repaired or replaced, the zero position may have been affected. Note any discrepancy in the field equipment log and notify the laboratory manager.

3. Clean the tape just before each measurement. Wipe the tape and/or rinse with tap water as necessary to remove any dirt. Rinse the lower 5 feet of the tape with distilled or deionized water. If the well is to be used for organics sampling, use organic-free water.

**OPERATING
PROCEDURES:**

Measurement methods: Two measurement methods are described--namely, measurement with popper and measurement with electric tape. Use of appropriate method should be determined based on the existing conditions and upon discussions with the project hydrogeologist and QAO.

Measurement with Popper

1. This method is simple, fast, and fairly accurate. It is preferred for most measurements, particularly in shallow wells. Precision is approximately ± 0.02 feet but may be less under unfavorable conditions. Accuracy depends on the tape used. Occasionally conditions in the well or outside noise will make it impossible to hear the popper, and measurements with electric tape should be employed.
2. Lower the tape into the well until the hollow-bottomed weight strikes the water surface and causes a popping sound. Hold the tape near the measuring point, and raise and lower several times to determine the water surface as closely as possible.
3. Record the actual number of feet that appears opposite the measuring point, i.e., do not add the "popper correction"--the distance from the tape zero mark to the bottom of the popper--before recording the number. Read the tape to the nearest ± 0.01 ft. Record the popper correction separately on the form, then add the two to obtain the depth to water.

Measurement with Electric Tape

1. This method is often considerably less accurate than the popper or chalk methods. Its precision is often limited to ± 0.10 feet or less by uncertainties in interpreting the sensing meter. Accuracy may be as low as 1% (i.e., 1 foot error in 100 feet) in measuring deep wells because of tape stretching. This method should be used with caution if high accuracy is important, for example in pumping tests. It may be preferred, however, in deep wells where other methods are not feasible, where cascading water is present in the well, or in noisy situations.
2. Turn on the electrical water sensor. Lower the tape into the well until it produces a meter or other response. Raise and lower the tape a few times to confirm that the water level has been detected.
3. If the tape is not calibrated to ± 0.01 feet, grasp the tape opposite the measuring point. Record the value of the nearest calibrated point; for example, if the tape is marked at 5-foot intervals, record the value of the nearest 5-foot marker on the water level record form.
4. Using a pocket rule, measure and record the distance from the measuring point to the nearest marker. If the measuring point is above the marker, record this distance as positive (+), or if below as negative (-).
5. Add the two readings algebraically to obtain the depth to water.

Record Keeping: Whenever possible, use standard Dames & Moore preprinted forms, since these will minimize the risk of missing some important bit of information. If taking notes in a field log, however, the following should be recorded:

- o Well number and location. All too often a single well is assigned two or more different numbers; if at all possible, record them all to avoid confusion for future users of the records.
- o Date and time of measurement.
- o Field observer's name.
- o Serial number of tape used.
- o Measuring point description, including whenever possible, its sea level elevation and stickup (the distance from the ground surface to the measuring point). Be sure to note whether the measuring point is above or below ground surface.
- o Method of measurement.
- o Tape readings, as described above.
- o Factors that may influence the water level--for example, recent pumping of the well or nearby wells.
- o Damage or alterations to the well or settlement that may have occurred since the last measurement.

As soon as possible, the measurements should be reduced in the office to elevation above sea level for long-term data storage. This is important because alteration or damage to wells changes the measuring point elevation, so that measurements of depth to water before and after this change are not comparable. The resulting confusion is difficult to sort out.

Whenever possible the same tape should be used for all measurements in a well. This is particularly important to pumping or slug tests, where small changes in water level are more important than the actual water level. Small differences between the readings from different tapes may entirely obscure these small changes.

Well Survey: During well survey, the surveyor should obtain elevations of both the measuring point and the ground surface. If a concrete pad surrounds a well, a survey marker should be embedded in it and the surveyor should determine its elevation. This allows easy determination of a new measuring point elevation if the well is damaged or modified.

SOP NUMBER: C.10

DATE: September 1989

TITLE: Abandonment of Wells and Borings

SCOPE: This procedure describes the steps involved in closure of wells and borings that are to be abandoned.

OBJECTIVE: To identify an approved method of well and boring abandonment techniques to protect the integrity of the subsurface environment and underlying aquifer, since improperly sealed boreholes/wells can provide a direct conduit for surface runoff and contaminants to reach the subsurface.

EQUIPMENT:

- o Drill rig
- o Logging chain, 15-inch minimum
- o Boring logs
- o Grout tank
- o Grout mix (cement, bentonite, water)
- o Tremie pipe
- o Grout pump.

PROCEDURES: Abandonment of Wells

Prior to abandonment, the protective casing and surface seal shall be removed from the well, the well shall be overbored and, to the extent possible, all casings, riser pipe, screen, grout, and filter pack material shall be removed. Any casing left in place shall be thoroughly ripped or perforated prior to sealing. In addition, the screened interval shall be scaled separately, and the seal tested, prior to sealing the remainder of the borehole.

Abandoned wells constructed under this project shall be sealed by grouting from the bottom of the well to ground surface. This shall be done by placing a grout pipe to the bottom of the well (i.e., to the maximum depth drilled/bottom of well screen) and pumping grout through this pipe until undiluted grout flows from the well at ground

surface. Any open or ungrouted portion of the annular space between the well casing and borehole will be grouted in the same manner.

After 24 hours, the abandoned site shall be checked for grout settlement. That day, any settlement depression shall be filled with grout and checked 24 hours later. This process shall be repeated until firm grout remains at ground surface.

Grout shall be composed by weight of 10 parts cement (portland cement, any of types I to V) to 0.5 part bentonite with a maximum of 8 gallons of approved water per 94-pound bag of cement. Neither additives nor borehole cuttings shall be mixed with the grout. Bentonite shall be added after the required amount of cement is mixed with water. All grout materials shall be combined in an aboveground rigid container and mixed onsite to produce a thick, lump-free mixture.

Abandonment of Borings

At the completion of soil sampling, all soil borings will be abandoned in the manner described above. Shallow borings 5 feet or less in depth that do not penetrate the water table will be backfilled with material of equal or lower permeability than the surrounding material to avoid creating a potential contaminant conduit. Borings that penetrate the water table will be sealed with grout following the steps above for abandoned wells.

SECTION D

Field Monitoring and Measuring Instruments

SOP NUMBER: D.1

DATE: August 1988

TITLE: pH Meter

SCOPE: This operating procedure describes the operation, calibration, and maintenance of pH meter and its accessories for use in the field. Manufacturer's specifications and recommendations should be followed or referred to as and when need arises.

OBJECTIVES: The activities covered by this procedure:

- o Ensure quality control in field pH measurement.
- o Provide uniformity and continuity in operation, calibration, and maintenance of both the equipment and measuring techniques by different qualified field analysts or technicians.
- o Serve as a means to allow traceability of error in analytical results.
- o Provide semiquantitative data in terms of the acidity or alkalinity of the water (surface water and/or groundwater) samples.
- o Indirectly serve as a means to evaluate the water quality at the time of sampling. It is imperative that temperature compensation is made for precise pH measurement.

EQUIPMENT:

- o pH meter* and its accompanying electrode or probe
- o Buffer solutions of known pH (4.0, 7.0, and 10.0)
- o Plastic or glass beakers or cups (as least 20 ml volume)
- o Distilled or deionized water
- o Polyethylene spray bottle
- o Waterproof marking pen or pencil
- o Liquid waste container
- o Thermometer

- o Trash receptacle

*Portable pH meters available with Dames & Moore for use in field include 1) LaMotte pH meter: model HA series and 2) Fisher Scientific Mini Analog pH meter: model R-5988-00.

**PRELIMINARY
TO OPERATION:**

1. At the start of each field trip, the pH meter should be examined for cleanliness and checked for defects and any possible need of repair. The checks should include the battery and electrode.

Battery check should include measurements to determine if it is functional to full scale. Batteries are replaced if found weak.

Electrode check consists of the following:

- o Make sure the electrode is properly connected to the meter.
- o The electrode tip should be covered by a rubber sleeve or cap that protects the electrolyte from flowing out of the opening or from drying. Pull the cap off and save for storage. There is normally no need to soak the electrode before, use as the electrolyte makes direct contact with the outside liquid once the rubber sleeve is moved away from the opening.
- o If bubbles are seen in the bulb area of the electrode, shake the electrode downward. This action will help eliminate bubbles that may have been generated during storage or earlier shipment.

Scheduled maintenance will include daily checks by Dames & Moore trained personnel according

to procedures provided by the equipment's manufacturer.

Repairs will be performed by an authorized service representative.

OPERATING PROCEDURES:

1. Remove pH meter from the box.
2. Check batteries to ensure they are operable.
3. Turn on power.
4. Allow meter to stabilize for about three to five minutes. Caution: Do not leave or use meter in direct sunlight or cold wind.
5. Calibrate the meter. Calibration schedule should include daily calibration, as well as intermittent calibration when required during continuous use of the meter. Instrument calibration consists of the following steps:
 - o Select two buffer solutions obtained from a commercial supplier such as Fisher Scientific Company (pH 4 and 7 if acidic conditions are expected of sampling water or pH 7 and 10 if alkaline conditions are expected). Source or origin of the buffer solutions should be recorded in field log.
 - o Label two clean and dry plastic or glass beakers or cups with the respective pH values of selected buffers.
 - o Place approximately 10 ml of each buffer in the respective cups and replace the buffer containers in the case.
 - o Measure temperature of buffers using a clean thermometer. Ensure that the thermometer is rinsed with distilled water before and after each use.

- o Rinse electrode with distilled water and replace protective cap.
- o Place pH electrode in pH 7.0 buffer solution and set the temperature knob at the mark indicating the solution temperature.
- o Switch the control knob to the "pH" position. Gently swirl the solution. Adjust the "STANDARDIZE" knob until meter reads a pH of 7.0. Switch meter to the "OFF" position after calibration is complete at pH 7.0.
- o Measure the temperature of the other buffer solution and set the temperature knob at the mark indicating the solution temperature.
- o Rinse the electrode with distilled water and place in the buffer solution. Gently swirl the solution. Turn the instrument switch to the "pH" setting and read the pH value directly from the meter face.
- o If the instrument does not read proper pH unit, adjust to proper pH reading with the calibration dial. (For LaMotte model HA series, carefully remove the panel by unscrewing the four screws on the front of the unit and lift unit out. Slowly rotate the trimmer potentiometer located next to the battery while examining meter reading until meter reads exactly desired pH unit. Check adjustment by following the preceding four steps above and readjust if necessary as in this step until meter and electrode are calibrated to the buffer solution(s). Switch meter to "OFF" position. Replace panel and the four screws.) Calibration details are logged on the instrument calibration log form (Figure A.1-10) and the field equipment logbook.

6. Measure pH of unknown solution as follows:

 - o Measure temperature of unknown solution and buffer to calibrate or standardize the meter.
 - o Set the temperature knob at the mark indicating the buffer solution temperatures. Switch control knob to "pH" position and with standardize knob adjust instrument to read value of standard buffer solution(s) as described in step 5.
 - o Rinse all parts of electrode that came in contact with buffer solutions with distilled or deionized water and place in unknown solution to be tested.
 - o Set temperature knob at the mark indicating the solution temperature.
 - o With control knob in "pH" position, read pH value directly from meter scale.
 - o When reading is completed, switch instrument to "OFF" position and store electrode in either pH 7.0 buffer solution or distilled or deionized water.
 - o Record buffer solutions used for calibration, temperature of buffers and unknown solution, and the pH reading of unknown solution on log sheet.
7. Quality assurance objectives of pH measurement based on EPA method 150.1 - Electronic measurement of pH (EPA, 1983)* should consist of: Precision (standard deviation): \pm 0.1 pH unit accuracy determined based on instrument manufacturer's specific value as follows:

\pm 0.1 pH value (LaMotte Model - HA Series)

\pm 0.15 pH value (Fisher Scientific Mini Analog pH meter - Model R-5988-00).

*USEPA 1983. Methods for chemical analysis of water and wastes. Environmental monitoring and support laboratory, office of research and development. EPA-600/4-79-020. U.S. Environmental Protection Agency, Cincinnati, Ohio.

SOP NUMBER: D.2

DATE: August 1988

TITLE: Conductivity Meter

SCOPE: This procedure describes the operation, calibration, and maintenance of the conductivity meter for conductivity measurements and use in field sampling activity. Manufacturer's specifications and recommendations should be followed or referred to as and when needed.

OBJECTIVES: The activities covered by this procedure:

- o Ensure quality control in conductivity measurement in the field.
- o Provide uniformity and continuity in operation, calibration, and maintenance of the equipment and in measuring techniques by different qualified field analysts or technicians.
- o Serve as a means to allow traceability of error in analytical results.
- o Provide semiquantitative data for use in determining relative variations in conductivity between two or more water (surface and/or groundwater) samples.
- o Indirectly serve as a means to evaluate the water quality at the time of sampling. It is imperative that temperature compensation be made, for precise conductivity measurement.

EQUIPMENT:

- o Conductivity meter*
- o Reference solutions
- o Thermometer
- o Plastic cup or beaker (at least 20 ml volume)
- o Distilled water
- o Polyethylene wash bottle
- o Trash receptacle

*Portable conductivity meters available with Dames & Moore for use in field include 1) Fisher model 152 - conductivity meter (manufacturer: Fisher Scientific Company), and 2) S-C-T meter-model 33 (manufacturer: Yellow Springs Instrument Company).

PRELIMINARY
TO OPERATION:

1. At the start of each field trip, the conductivity meter should be examined for cleanliness and checked for defects and any possible need of repair. The checks should include whether the battery is operable, whether the conductivity meter is zeroed, and whether its probe is conditioned for proper functioning.

Battery check should be performed as follows:

- o Turn function selector to "BATTERY" position.
- o Set power switch to "ON."
- o Observe if meter pointer deflects to the BATT bracketed okay area.
- o If indication is unsatisfactory, replace batteries.

Adjust meter mechanical zero if necessary with a small screwdriver until the meter pointer precisely shows "0" with power switch "OFF."

Conditioning the probe is necessary when using a new probe for the first time or when using a probe stored for an extended period of time (3 months or more). To condition a probe, perform the following:

- o Thoroughly wet probe by immersing it in distilled water.
- o Soak probe in 2-propanol for 10 to 20 minutes.

- o Thoroughly rinse probe with distilled water.
- o Keep probe wet by storing it in distilled water between uses.
- o Make sure inside of probe is devoid of air bubbles.

Scheduled maintenance will include daily checks by Dames & Moore trained personnel according to procedures provided by the equipment's manufacturer.

Repairs will be performed by authorized service representative.

**OPERATING
PROCEDURES:**

1. Make sure preliminary operating procedure is conducted.
2. Recheck battery level (see above) before using the meter.
3. Calibrate or standardize the instrument. Instrument calibration can be achieved by one of the two following methods: standard solutions or internal reference.

Calibration Using Standard Solutions

- o Select a standard solution having a conductivity value near expected value of water sample. Standard solution should be of known integrity.
- o Measure temperature of the standard solution.
- o Turn "FUNCTION" selector to " 25 - automatic temperature."
- o Turn conductivity "RANGE" selector to lowest position that will accommodate the conductivity of the value standard solution on the readout meter.

- o Set power switch to "ON" and immerse probe in solution, ensuring that probe is immersed to a depth to cover the vent holes. When immersing probe, dip it up and down in solution to expel any air bubbles inside and immediately outside the probe body.
- o Allow meter to equilibrate, then unlock and adjust the "STANDARDIZE" control until meter indicates known value of standard solution on conductivity scale.

Calibration Using Internal Reference

- o Remove probe plug from "INPUT" jack.
 - o Set function switch to the position to measure conductance uncorrected for temperature.
 - o Set "RANGE" selector to "X1K" (i.e., multiple to conductivity scale on readout meter.)
 - o Set POWER switch to "ON."
 - o Adjust "STANDARDIZE" control until meter indicates 0.500 on the conductivity scale, i.e., a result of 500 umhos/cm. This procedure standardizes all ranges. Record all calibration information and data on log sheet and the field equipment log. A copy of the Dames & Moore instrument calibration log is shown in Figure A.1-10.
4. After standardization, turn "FUNCTION" selector to "25" (corrected conductivity to 25°C) position.
 5. Select "RANGE" to maximum (x100k).
 6. Set power switch to "ON."
 7. Immerse probe in test solution, being certain that vent holes are covered, that all air has been expelled, and

that probe is not in contact with the walls or bottom of the sample container.

8. If meter indication is below 0.1 on the conductivity scale, turn "RANGE" selector counterclockwise to obtain highest on-scale indication.
9. Note meter indication on conductivity scale. Indication multiplied by "RANGE" selector setting equals conductivity corrected to 25°C.
10. Remove probe from sample solution and rinse it thoroughly in distilled water before proceeding to measure next samples or putting away the equipment.
11. Record data on log.
12. Quality assurance objectives of conductivity measurement based on EPA method 120.1 (specific conductance, umho's at 25°C) (EPA 1983)* should consist of:

Precision (standard deviation)--+ accuracy determined based on instrument manufacturer's specific value, such as $\pm 3\%$ for Fisher scientific model 152 conductivity meter and 33m S-C-T probe.

*USEPA 1983. "Methods for Chemical Analysis of Water and Wastes." Environmental Monitoring and Support Laboratory, Office of Research and Development. EPA-600/4-79-020. U.S. Environmental Protection Agency, Cincinnati, Ohio.

SOP NUMBER: D.3

DATE: August 1988

TITLE: Thermometer

SCOPE: This operating procedure describes the operation, calibration, and maintenance of a thermometer and its accessories for use in the field. Manufacturer's specifications and recommendations should be followed or referred to as and when need arises.

OBJECTIVES: The activities covered by this procedure:

- o Ensure quality control in field temperature measurement.
- o Provide uniformity and continuity in operation, calibration, and maintenance of both the equipment and measuring techniques by different qualified field analysts or technicians.
- o Serve as a means to allow traceability of error in analytical results.
- o Provide quantitative data in terms of temperature of the water (surface water and/or groundwater) samples.
- o Indirectly serve as a means to evaluate the water quality at the time of sampling. It is imperative that temperature compensation be made, for precise analytical measurements such as pH and conductivity.

EQUIPMENT:

- o Thermometer* with mercury bulb, or probe in modern meters
- o Field log

*Thermometer available with Dames & Moore for use in the field is Digi-Sense model 8523-00.

PRELIMINARY TO OPERATION:

1. Examine the thermometer for cleanliness, defects, and any possible need of repair. The checks should include the battery and probe.

2. Verify that the thermometer has been calibrated at the factory against National Bureau of Standards Traceable Instrumentation criteria.

**OPERATING
PROCEDURES:**

1. Slide switch toward display to turn the unit on.
2. If the "LOW-BAT" notation is present in the display, replace battery.
3. Plug the jacks on the probe into the thermometer.
4. Stir liquid continuously while measuring temperature.
5. Record measured temperature in field log and other required information on the Field Sampling Sheets.
6. Decontaminate probe when finished.

SECTION E
Testing Procedures

SOP NUMBER: E.1

DATE: August 1988

TITLE: Grain Size Distribution (Based on ASTM Method D422)

SCOPE: This method describes the procedure for quantitative determination of the particle size distribution in soils.

OBJECTIVE(S): The activities covered by this procedure

- Allow engineering correlations concerning the behavior of subsurface materials including physical characteristics such as porosity, permeability, hydraulic conductivity.
- Allow estimation of chemical absorption potentials of soil aggregates.

EQUIPMENT:

- A balance capable of weighing to nearest 0.01 grams
- Mechanically operated stirring device (stainless steel mixer)
- Hydrometer #152H (ASTM standard)
- 1,000 ML glass sedimentation cylinder
- Thermometer capable of measuring to nearest 1°F
- ASTM standard square mesh woven wire sieves
 - Sizes 3 in. (75mm) - Sieve No. 20 (850 um)
 - 2 in. (50 mm) - Sieve No. 40 (425 um)
 - 1½ in. (37.5mm) - Sieve No. 60 (250 um)
 - 1 in . (25 mm) - Sieve No. 140 (106 um)
 - 3/4 in. (19 mm) - Sieve No. 200 (75 um)
 - 3/8 in. (9.5 mm)
 - No. 4 (4.75 mm)
 - No. 10 (2.000 mm)

- mechanical sieve shaker
- sample splitter
- Dispersing solution - 40g metaphosphate/liter distilled H₂O
- Water Bath - at 68°F
- 250 ml glass beaker
- a watch or clock with a second hand
- distilled water
- metal drying pan
- mortar and rubber covered pestle
- drying oven capable of 250°F.

**PRELIMINARY
TO OPERATION:**

1. Prepare the test sample (based on ASTM Method D421).
 - 1.a Air dry the soil sample received from the field at room temperature.
 - 1.b. Break up clods or soil aggregates in a mortar with rubber covered pestle.
 - 1.c. Select a representative sample and record the mass as the mass of the total test sample.
2. Prepare all data sheets including - grain size analysis-mechanical, grain size analysis-hydrometer method and a gradation curve.

**OPERATING
PROCEDURE:**

1. Divide sample into two portions by sieving; one portion to contain only particles retained on the No. 10 (2.00 mm) sieve while the other portion to contain only particles passing the No. 10 sieve.
 - 1.a. Sieve portion retained on the No. 10 sieve into a series of fractions using sieves 3 in. (75 mm) thru

No. 10 (2.00 mm) by using a mechanical sieve shaker.

- 1.b. Determine the mass of each fraction on a balance. The sum of the masses retained on all sieves should equal the original mass of the quantity sieved.
- 2.a. Weigh out a portion of the test sample (50 grams for clay and silt textured soil and 100 g for coarse textured soils) which passed the No. 10 sieve.
- 2.b. Place the sample in the 250 ml beaker and add 125 ml of dispersing solution. Stir to mix contents well and allow them to stand for at least 16 hours.
- 2.c. Disperse the mixture further using a stainless steel mixer for one minute.
- 2.d. After dispersion transfer soil-water suspension to a glass sedimentation cylinder and fill with distilled water to 1,000 ml volume.
- 2.e. Place a rubber stopper over the end of sedimentation cylinder and turn cylinder upside down and back for one minute to mix contents well.
- 2.f. At the end of the one minute set cylinder down and begin taking hydrometer readings at the following intervals 2,5,15,30,60,250 and 1,440 minutes.
- 2.g. Set the sedimentation cylinder into water bath set at (68°F) between the two and five minute readings.
- 2.h. When taking a hydrometer reading, insert the hydrometer about 20 seconds before

- measurement (all readings should be taken to the lower end of meniscus).
- 2.i. At the end of each reading, measure the temperature of the suspension.
 - 2.j. After taking the final hydrometer reading transfer the suspension to a No. 200 (75 um) sieve and wash with tap water until the wash water is clear. Transfer the material retained on the sieve to a metal drying pan and dry in an oven at 230°F.
 - 2.k. Complete a mechanical sieve analysis on the portion retained on the No. 200 sieve.
 - 2.l. Calculate to determine the percent soil aggregates from the data generated tests. The grain size analysis-mechanical and grain size analysis-hydrometer method forms will be used to record data (Figures E.1-1 and E.1-2). Plot and graph the data on the Graduation Curve Form (Figure E.1-3).

FIGURE E.1-1

GRAIN SIZE ANALYSIS-MECHANICAL

Project _____ **Job No.** _____

Location of Project _____ Boring No. _____ Sample No. _____

Desiccation of Soil _____ **Depth of Sample** _____

Tested by _____ Date of testing _____

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum WL of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt of dry sample + container

WL of container

WL of dry sample. W.

Sieve analysis and grain shape

$$\% \text{ passing} = 100 - \sum \% \text{ retained.}$$

FIGURE E.1-2

GRAIN SIZE ANALYSIS - HYDROMETER METHOD

Project _____ **Job No.** _____

Location of Project _____

Description of Soil _____

Tested By _____ Date of Testing _____

Hydrometer analysis

Hydrometer no. _____ C. of solids = _____ o = _____ (See Table 1)

Dispersing agent _____ Amount _____ Wt. of soil, W. _____

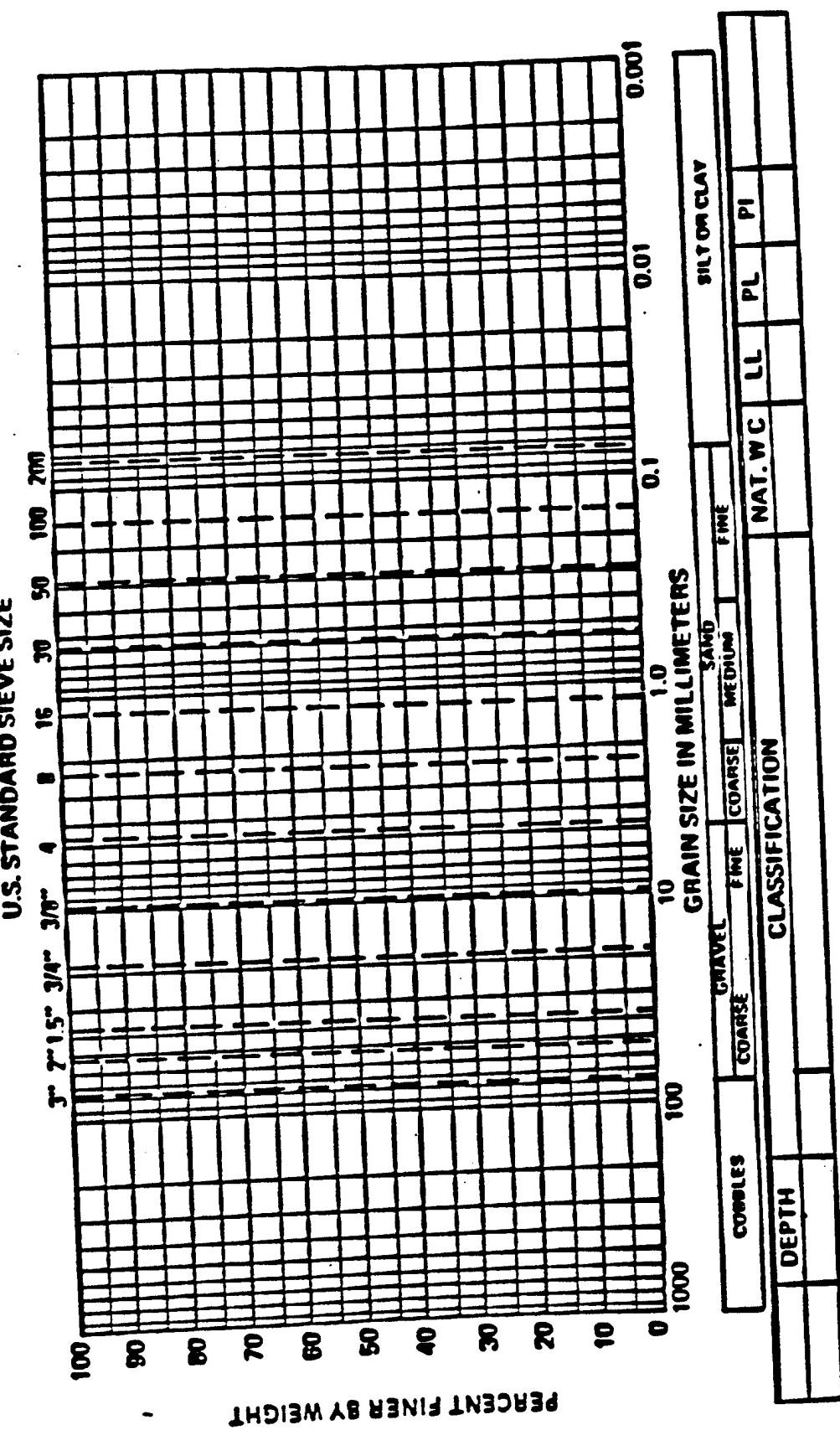
Zero correction _____ **Meniscus correction** _____

$$R = R_{\text{true}} - \text{zero correction} + C,$$

$$\% \text{ finer} = R_s(s) NW.$$

$$p = \kappa\sqrt{L/\pi}$$

**FIGURE E.1-3
GRAIN SIZE GRADATION CURVE**



SOP NUMBER: E.2

DATE: August 1988

TITLE: Specific Gravity Determination (Based on ASTM Method D854)

SCOPE: This method covers determination of the specific gravity of soils by means of a pycnometer.

OBJECTIVE(S): The activities covered by this procedure

- Allow calculations of grain size determination by the hydrometer method
- Allow engineering correlations to be made concerning subsurface densities and volumetric relationships

EQUIPMENT:

- pycnometer - a 500 ml glass volumetric flask
- a balance sensitive to 0.01 grams
- oven capable of drying at 250°F
- metal drying pan
- distilled water
- polyethylene spray bottle
- aspirator apparatus
- rubber stoppers
- thermometer sensitive to 0.1°C

PRELIMINARY TO OPERATIONS:

1. Clean, dry, weigh and record the weight of the pycnometer.
2. Fill the pycnometer with distilled water and weigh at room temperature.
3. From this weight prepare a table of values of weights of pycnometer maintained at different temperatures.
4. Oven dry the sample for 12 hours at 230°F (110°C), allow to cool weigh out at least 25 grams.

5. Mix sample in distilled water for at least 12 hours.
6. Prepare test sheet.

**OPERATING
PROCEDURE:**

1. Place approximately 25 grams of sample into pycnometer and add distilled water to about 3/4 full.
2. Connect the pycnometer directly to the aspirator apparatus removing any entrapped air.
3. Fill the pycnometer with distilled water, clean the outside and dry.
4. Determine the weight of the pycnometer and the temperature in degrees celsius.
5. Complete 3 to 4 trials for each sample, calculate the specific gravity from data generated, determine the average value, and record the data on the Specific Gravity of Soil Solids form (Figure E.2-1).

FIGURE E.2-1

SPECIFIC GRAVITY OF SOIL SOLIDS (C_s)

Project _____ Job No. _____

Location of Project _____

Description of Soil _____

Tested By _____ Date of Testing _____

Test no.				
Vol. of flask at 20°C				
Method of air removal*				
W _L flask + water + soil = W _{soil}				
Temperature, °C				
W _L flask + water ^b = W _{sw}				
Evap dish no.				
W _L evap. dish + dry soil				
W _L of evap. dish				
W _L of dry soil = W _s				
W _s = W _s + W _{soil} - W _{sw}				
C _s = sW _s /W _{sw}				

*Indicate vacuum or aspirator for air removal.

^bW_{sw} is the weight of the flask filled with water with the same quantity of dispersing agent as added to the soil-water mixture and at the same temperature.

Remarks _____

Average specific gravity of soil solids (C_s) = _____